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GEOPHYSICAL FACTORS IN NAVAL AND MARINE OPERATIONS

July 1966
7662-212

Scott D. Thayer
Thomas G. Johnson
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FOREWORD

This report describes the second contract year of study aimed ultimately at developing warfare system concepts that include consideration of, and exploitation of, geophysical factors and man's increasing present and potential abilities to better predict, to modify, or to control them. This study [prepared for the Office of Naval Research under Contract Nonr 4112(00) to the U.S. Navy], based on the findings of the first year's study [1], has taken another step in the direction of that long-range objective.

Following the introductory discussion of the background for this study, Section 2.0 discusses its objectives and scope; Section 3.0 summarizes the narrowing down, in a logical fashion, of the spectrum of military missions to one of special interest, the amphibious operation, and then to a single mission activity for detailed analysis (the mission selection is described in Appendix A). Section 4.0 presents an analysis of the mission activity, the surface ship-to-shore movement (detailed in Appendix B), a discussion of the environmental impacts on the operation, and a discussion of an available simulation model (described in Appendix C), its input data, its use, and its results. Sections 5.0, 6.0, and 7.0 present findings, conclusions, and recommendations, respectively.

The scientists and analysts who conducted this research acknowledge here the willing cooperation and assistance of the Navy and Marine Corps personnel who were interviewed in the course of this study, especially the individuals and the members of the units cited in Appendix D; the helpful information provided by the personnel of Stanford Research Institute's Naval Warfare Research Center is also acknowledged.

This study could not have been carried out without the contributions and help, in particular the computer runs and program changes in the STS-2 simulation model, and the cooperation of the personnel at the U.S. Naval Weapons Laboratory, Dahlgren, Virginia; special thanks are due Mr. Oliver Braxton of that installation.

A final grateful acknowledgement is due Mr. Robert C. Hetzel of The Travelers Research Center's Publications Division, whose technical contributions and unflagging assistance during the preparation of this report far exceeded that normally involved in technical editing.

ABSTRACT

Computer simulation is assessed as a means of acquiring quantitative values of the effects that geophysical factors have on Naval and Marine operations. This work is part of a long-range program to develop warfare system concepts that will include, and in part depend on, the effects of changing environmental conditions, to enhance the probability of mission success by improving the prediction, modification, or control of relevant geophysical phenomena. An appropriate military operation and a corresponding computer simulation were sought concurrently: the Naval Weapons Laboratory's STS-2 Simulation Model was tested against the ship-to-shore portion of the amphibious operation (selected from among fifteen military missions previously determined most susceptible to potential geophysical prediction, modification or control possibilities). This report covers the operation selection study and the detailed analysis of the selected ship-to-shore movement, eliciting the problems of and then quantifying the appropriate geophysical effects, and the results of computer runs of the STS-2 simulation model. It was found that, while the STS-2 and other present models cannot completely reflect this quantification of geophysical impact (primarily because they were not designed with this objective), simulation is still feasible, but will probably require (1) a new, more complex simulation model and (2) a large-scale data compilation and analysis effort. This effort would be justified by the wide ranging applications that such a program might have. Other methods of quantifying the impact of geophysical parameters on complex naval operations should also be sought.

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1.0 INTRODUCTION

In June, 1963, The Travelers Research Center, Inc. (TRC), undertook an exploratory study of the potentialities of the prediction, modification, or control of geophysical phenomena for Naval and Marine applications, under Contract Nonr 4112(00) to the U.S. Navy. The long-range intent of the direction of study, which the first year's contract began, is to develop warfare system concepts that include consideration of, and exploitation of, geophysical factors and man's increasing present and potential abilities to better predict, to control, or to modify them. The first year's work is detailed in a two volume report [1] and is summarized below.

More than two hundred and fifty geophysical factors were considered capable of affecting, in some degree, about thirty-four major Navy and Marine Corps missions. Many of these factors exhibited several distinct facets or stages, each of which had its own unique military significance. Practical limitations in time and funds required that detailed feasibility studies be limited to those factors of highest potential military importance and technological promise. Although a quasi-objective methodology was developed for the selection process, budget limitations precluded its use and a qualitative judgmental procedure, which included ONR review, was used instead.

The thirty-four geophysical phenomena and situations selected as being of greatest military significance were examined in detail for scientific and technological feasibility both of prediction and control. The predictability of each phenomenon by both statistical and dynamic techniques was assessed, and the extent to which present techniques have succeeded in realizing this predictability was reviewed. Considerable scope for extending and improving present methods was revealed and the most promising avenues for advance in prediction, modification, or control capabilities were specified. Similarly, the energy budgets and conversion processes associated with each were studied quantitatively, and the most likely modification opportunities were identified, considering the kinds of energy resources available to technology during the next five to fifteen years.

As a result, some fifteen military missions were identified as most susceptible to potential geophysical prediction, modification, or control possibilities; these were examined in a formalism which indicated their relative sensitivity to those possibilities.

Conversely, and at the same time, the thirty-four geophysical phenomena were ranked in the order of their overall military importance to these missions. The results were further reviewed for consistency with common-sense concepts of warfare and military utility in the light of the detailed behavior of the relevant geophysical phenomena.

This exploratory study resulted in part in the identification of several phenomena that might most reasonably be exploited to enhance the success of Naval and Marine operations, as well as the means by which this enhancement might be achieved. These are: dispersal of fog and low stratus, the smoothing of sea-surface waves, and the improved prediction of fog, wind, and surface waves.

Among the recommendations made in the first year's study was that "operations analyses be undertaken on the exploitation of prediction," and that this be done "as a preliminary to a research program on the development of control techniques."

However, because it is not feasible to attempt to control, or to improve prediction of, all of even these few relevant geophysical factors in all the selected military mission contexts, a method must be found to select from among them a more limited, more immediate goal.

A rational criterion for the definition of a research effort would be to attack those areas where improvements in prediction or control would provide the greatest marginal benefit. Although other ways should be sought, and may be found, the only presently available methodology for assessing such marginal utility in complex situations is simulation. Therefore, determining the means for, and the feasibility of, simulating military activities in a way that would include the effects of varying environmental conditions is the next logical step in the pursuit of the long-range goals.

The study reported here, conducted between May 1, 1964 and July 31, 1965, analyzes a naval operation simulation in order to assess the feasibility of such simulation analysis for further studies to develop warfare system concepts utilizing geophysical information developed in the previous study [1]. The problems in applying simulation are never trivial, and in general require considerable exploration to establish those salient features of the operational problem which must be modeled. This, of course, has been done before. Simulation has been conducted in many contexts and for many purposes. Notably, the Naval Weapons Laboratory (NWL) has developed and used simulation models for evaluating contingency war plans for specific amphibious operations. Such a simulation model served as the basic research tool for the study reported here. However, neither these simulation models, nor any others, have been designed or used specifically to study the exact impact points of varying environmental conditions on detailed, small-scale operational activities, particularly with the intent of establishing quantitative measures of the adverse (or even beneficial) effects that the changing environment might have on the success of these military operations. Therefore, much background work was necessary to identify specific impact points, to define and accumulate quantitative measures of the actual environmental conditions, in a usable form, and to translate these measures into input data (a) that the simulation model would accept with minimum modification to the model, and (b) that would specify, or at least indirectly reflect, the changing environmental conditions or their effects on specific activities within the military operation.

The objectives and scope of this study are further detailed in the next section.

2.0 OBJECTIVE AND SCOPE

2.1 Objective

The goal of the line of study of which this report is part is the development of warfare system concepts that would include, and in part depend on, the effects of environmental changes on specific warfare missions, as well as the possible increased mission success that would follow from a greater ability to predict, modify, or control the relevant geophysical events. The basic information on which this course of study depends is the result of the first year's exploratory study outlined in Section 1.0.

The progression of events from the original analysis of geophysical factors and military missions (the first year's study) to the eventual goal—the final formulation of detailed warfare system concepts, which would embrace such considerations as operations orders, the organization and allocations of forces, the planning procedures requisite to field implementation, technical support activities, control and data processing systems, and special training requirements—is a long and complex progression. The first major step toward achieving this goal, after identifying the most relevant geophysical events and military missions, is to establish quantitative measures of the impact that environmental changes have on operations and activities, as a basis for selecting those prediction, modification, or control methodologies for concentrated study that will yield the highest marginal returns. Therefore, a means must be found to determine these quantitative measures. This, the means for this quantitation, is the subject of the work described in this report.

The only potentially available means for the required quantitation is computer simulation. However, because no simulation program has been constructed specifically to measure and assess in quantitative terms the importance of changing environmental conditions, the only alternatives are to develop a new simulation program or to adapt an existing model. The enormous cost of creating an entire simulation model precluded the first possibility within this study effort and so a study was made of the existing and available models.

The objective of this phase of the contract, then, was to investigate the feasibility of using computer simulation to study the quantitative impact of geophysical factors on naval operations.

The breadth of the subject and the level of effort that could be expended imposed limitations, which are discussed in the next section.

2.2 Scope

The scope of this contract year's work was partly dictated by the considerations discussed above and further delineated as a result of the selection of the Naval Weapon Laboratory's Simulation Model, STS-2. The STS-2 simulation model and its use in this study are described in detail in Appendix C. However, the limitations of this model—as with any model being used for a kind of analysis other than that for which it was designed—raise certain problems. Therefore, the final scope of the study was set to some extent by the number and kinds of problems raised, and the degree of success in solving them within the allocated time and manpower resources. The problems, the rationale for their solutions and the compromises that they necessitated, and the success with which they were resolved are all described in Appendix C.

The approach to analysis was conducted in accordance with the following considerations.

A naval mission was selected and a component function of it was defined for detailed study. The selected activity was outlined inductively and modeled by event simulation. Progress was facilitated by the use of one of the Navy's models describing specific naval missions or operations. The model was elaborated and articulated to concentrate on the points of interaction with the geophysical factors to be studied. The activity selected (see Section 3.0) was intended to be sufficiently comprehensive that the propagation of the geophysical influence could be followed far enough through the system to permit the assessment of the significance of introducing control aspects, as well as the utility—or lack thereof—of prediction, as compared with simply using constant-value climatological input.

It was recognized that this form of analysis would require certain compromises, the principles of which can be stated as follows.

Ideally a feasibility study such as this would employ a very detailed, large-scale model of a total mission against which to examine geophysical influences, because we are fundamentally interested not in the proximate technical effects of the geophysical factors, but in the more remote ramifications on the larger military system. This is expected to be found only by attempting to follow the perturbations at great length and in great detail. However, a workable compromise would involve a considered balance of:

(a) the number of geophysical factors and their modifications to be considered,

(b) the number of military activities (missions, functions, or operations) to be studied,

(c) the geographical extent of the activity to be modeled, and

(d) the degree of detail (or aggregation) employed in the model.

Because we wished to use the most detailed and most extensive model practicable [(c) and (d) above] we found it necessary to compromise by:

(a) limiting the number of geophysical inputs, and

(b) finding a model of naval activities that could be employed for all of the geophysical inputs to be studied.

However, even within these limitations, further compromises were necessary: the only remaining compromise available was employed, namely, to strike a balance between:

(a) the degree of detail that is necessary to permit introduction of the geophysical factors, and

(b) the horizontal extensiveness of the model.

From a practical viewpoint, the nature of the geophysical factors would generally specify the degree of detail that must be recognized, so the only variable remaining to be manipulated was the extensiveness of the model. As a result, it was not possible to study complete operations or even isolated major segments within operations. Rather, an attempt was made to isolate, from an appropriate mission, a critical military function or activity that could be dissociated from its broader context for detailed examination and yet be limited enough so that it was not impossibly burdensome.

The course of the project was thus a balanced, step-wise progression through the study of such a military activity, with a continuous exercise of judgement to maintain a manageable and yet meaningful scope of work. The following sections document this study.

3.0 THE SELECTION STUDY

It was apparent at the outset that only a very few missions could be studied in detail to achieve a quantitative definition of sensitivity to geophysical factors through mission simulation. The rationale for selecting these missions—and ultimately, the one mission, amphibious operations—is discussed in Appendix C and outlined below.

3.1 Selection of a Mission

The first year's study [1] discusses thirty-four discrete war missions in terms of their dependencies on eleven geophysical factors. Twenty of these missions were excluded from consideration because they either showed negligible dependency on geophysical effects or were constituents of larger missions. The remaining fourteen missions were ranked according to the number of geophysical factors to which they are sensitive, by two criteria (see Appendix A). Two missions, strengthening the will to resist and amphibious operations, headed the list. An evaluation of the mission-functions implied by each of the fourteen missions led to the selection of amphibious operations for simulation and further study, since this mission was determined to include the greatest number of mission-function and geophysical-factor impact points within a manageable context (again, see Appendix A).

With the isolation of a single mission, amphibious operations, for further analysis, it became necessary to find that part of the total mission that would meet the three criteria for successful simulation analysis:

(a) it must be sufficiently comprehensive to include a meaningful mix of operational functions and geophysical effects so that the interrelationship of decisions made in response to varying geophysical effects could be traced throughout the operation,

(b) it must be sufficiently constrained in scope to be manageable, and

(c) because of the enormous effort and expense of developing a simulation model, it should fall within the capacity of an existing model (see Section 2.2).

The rationale for selecting the surface ship-to-shore movement for simulation analysis is discussed below. Figure 3-1 is given to clarify the classification of operations

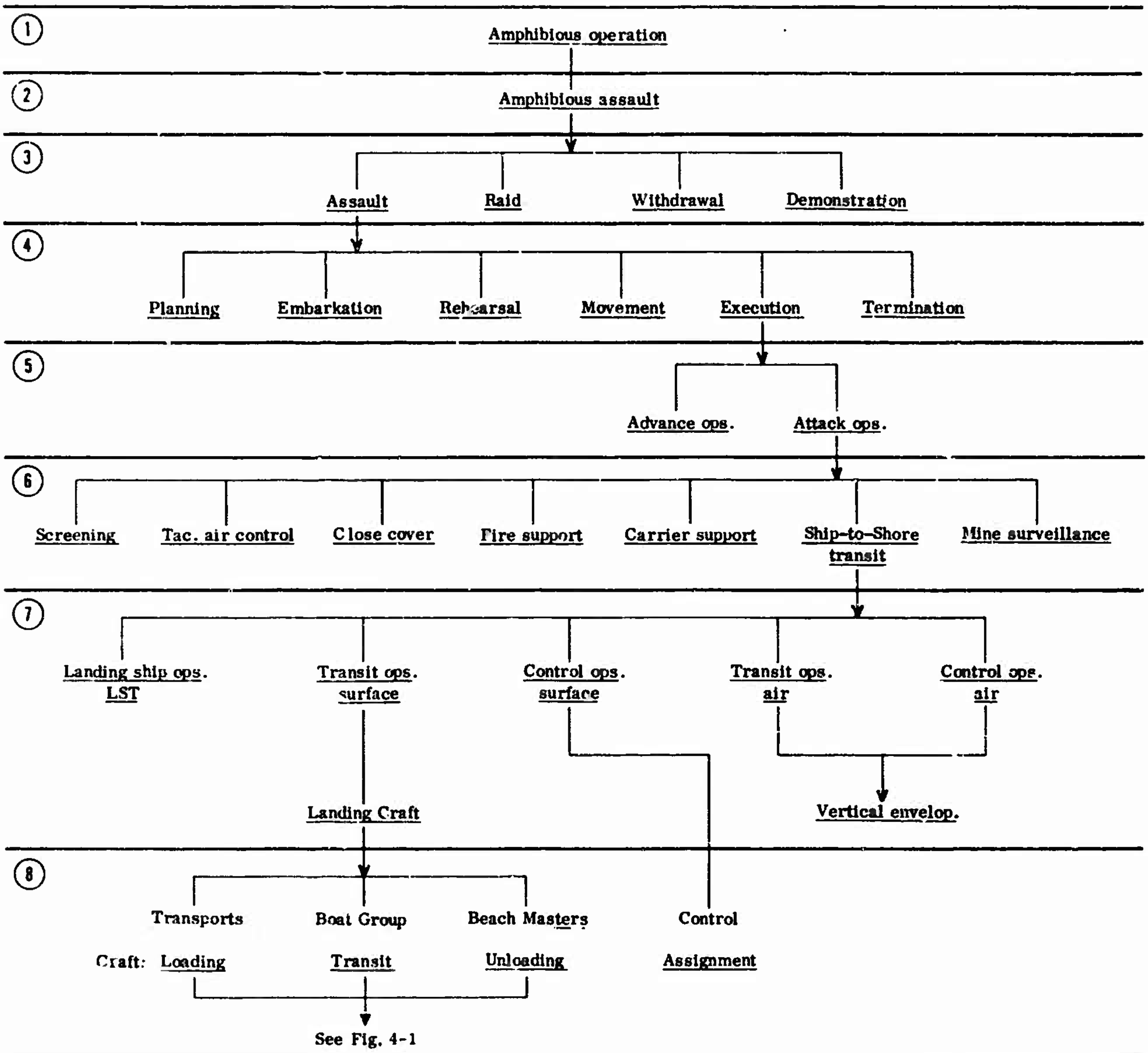

Fig. 3-1. Selection of the surface ship-to-shore operation.

within operations.

3.2 Selection of an Operation, Ship-to-shore Transit

Of the various operations within the selected mission*, the one which appeared most fruitful for environmental analysis is amphibious assault (Fig. 3-1, row 2). This operation has four major aspects: assault, raid, withdrawal, and demonstration. Of these, assault is selected: it comprises six phases (Fig. 3-1, row 4). The execution of the assault phase is divided into advance operations and attack operations. Of the seven attack operations, ship-to-shore movement best meets the selection criteria.

A closer look at the ship-to-shore transit function reveals, first, that it can be divided into surface and air transit and control operations, and second, that the landing ship (LST) surface operation can be considered separately because its dependencies on environmental conditions are distinctly different from those of smaller surface craft (Fig. 3-1, row 7). Thus, considering these distinctions, ship-to-shore transit comprises LST operations, surface landing craft operations, and vertical envelopment operations. Any of these operations is of the appropriate scale for analysis and each has characteristics to commend it for simulation and evaluation. Therefore, other considerations enter into the final selection and the further study of one operation.

One of these considerations was the availability of a ready-made simulation model. It was first thought that a simulation model could be developed especially for this type of analysis,but it soon became evident that this approach would be too expensive and time-consuming. Therefore, an existing simulation program was sought that could be used directly or modified to meet this study's needs. The search yielded two potentially-useful programs: NWL's STS-2 model and the Stanford Research Institute's MARADS model. Both were available, but neither had all the flexibility desired for this kind of analysis because each was originally designed for another purpose. In particular, each of these simulations is predicated on the assumption of a nominal (benign) environment and is not structured to permit the introduction of other, non-nominal environments (the surmounting of this difficulty is discussed in Appendix C). Because the Naval Weapons Laboratory was in a position to supply complete computer runs, and because NWL's desire to apply the STS-2 model to environmental problems

*This analysis is based on references [2] through [7].

gave them special interest in the success of the study, the STS-2 model was chosen. This choice, then, reflects these considerations: while both models were adequate (and using either was better than developing a new one), the immediate availability of computer runs and the ready access to program modification assistance at NWL, allowing diversion of research efforts and resources to other phases of the analysis, as well as NWL's interest and familiarity with the problem, favored NWL's STS-2 model.

With the adoption of the STS-2 model, further selection of a single operation for simulation analysis became dependent on the characteristics of the model and its adaptability to the project objectives. Within the ship-to-shore transit operation, the three component operations were (as discussed above): vertical envelopment operations, LST operations, and surface landing craft operations. The consideration of these alternatives, and the final selection of the surface landing craft operation for further analysis, is discussed below.

The first operation considered was <u>vertical envelopment</u>. The state of the environment has obvious and substantial impact on the vertical envelopment operation, to the extent that the operation cannot be undertaken without assurance of a relatively benign environment and, once begun, is very sensitive to short-period environmental fluctuations. Moreover, as the vertical envelopment assault operation progresses beyond the area of potential surface support, the limited helicopter flight endurance becomes vitally critical, and it is necessary to allocate a larger proportion of the vehicle's range-payload to the possibility of extra navigation or hover requirements. Here, control or improved prediction of geophysical factors would presumably contribute much to the probability of mission success.

However, the difficulties envisioned in determining the quantitative direct effects of environmental conditions on specific facets of the helicopter operations—such as the quantitative effects of reduced visibility on helicopter hover requirements, target search and assembly, and inter-craft visual communications, the quantitative effects of an adverse sea state on helicopter recall and landing operations, the quantitative effects of high wind, frequently associated with an adverse sea state, on helicopter navigation characteristics, and the quantitative effects of changing atmospheric conditions (electromagnetic propagation) on inter-craft radio communications—combined with a notable paucity of records of these effects, taken together, suggested that the alternative surface component operations of the ship-to-shore operation would yield more immediate and more reliable quantitative measures of environmental impacts. The extent of the data search that was necessary to support the subsequent analysis of the ship-to-shore transit operation (which appeared far more tractable than the vertical envelopment operation), which is discussed in Section 4.3 and described in Appendix D, later emphasized the difficulties that would have been entailed in deriving the quantitative data for the vertical envelopment operation.

LST operations, while apparently not as sensitive to environmental effects as vertical envelopment operations, are still of substantial interest for two reasons:

(a) When LST operations involve a beach that has a shallow gradient, causeway operations must be undertaken to make off-loading possible. Causeways are very sensitive to environmental conditions both at the beach and at the seaward terminus.

(b) When LST operations involve a beach with enough slope to dry-ramp the ships the LSTs are largely insensitive to sea state, surf, and wind conditions. In this case, with appropriate planning, the LSTs can haul the loads normally allocated (under better environmental conditions) to smaller craft and, to that extent, render the entire amphibious assault less sensitive to environmental influence.

However, the first restriction on the LST operation eliminated it from further consideration because the STS-2 simulation model had no provision for causeway operations, thus precluding the possibility of assessing environmental effects under those operating conditions. The assessment of using LSTs in the case of default by smaller surface craft under unfavorable conditions was also precluded by the very fact that such use is subordinate to, and interdependent upon, the effects of geophysical factors on the smaller craft. Thus, the analysis would have to coordinate LST operations with all other landing craft operations, which is beyond the scope that was possible in this study.

Therefore, the third possibility, landing craft operations, was selected for study—but not entirely by default: this is the operation that represents the major portion of the ship-to-shore assault operation that the STS-2 model simulates (see Appendix B), and the one in which the model is most flexible to adjustments that can be made to represent (indirectly) varying environmental conditions (see Appendix C). Further, an assault operation's order and administrative plan for a typical regimental landing team (RLT), available from NWL, had been specifically created for research purposes by the amphibious forces.

In sum, it was decided that the landing craft operations portion of the STS-2 model would provide a suitable basis for exploring the use of simulation in the assessment of environmental influences on an important and critical portion of a significant, environmentally-sensitive naval operation.

4.0 ENVIRONMENTAL ANALYSIS OF SURFACE SHIP-TO-SHORE TRANSIT

The surface ship-to-shore transit operation was analyzed in detail to identify those parts directly affected by changes in environmental conditions, to allow subsequent exploration of the impact that such changes affecting one part have on the rest of the operation. This was done by reducing the total operation to component activities and then, by relating these activities according to their interactions, options, and contingencies, identifying the operational decision points at which the flow of activity is determined during an actual exercise. This analysis, described and diagrammed in Appendix B, was conducted entirely independent of, but concurrent with, the analysis and use of the STS-2 simulation model (Appendix C) and did in fact contribute to the evaluation of STS-2.

While this operational analysis is not exhaustive and is based on limited study, it proved adequate for technique assessment, and served to dramatize the very finely detailed analysis that would be necessary for a truly comprehensive study. The information supporting the analysis was gleaned from Navy and Marine documents [2—7], interviews with representatives from other agencies and companies (notably Stanford Research Institute), and extensive, illuminating discussions with active-duty military personnel (see Appendix D).

4.1 Geophysical Factors Affecting Operation Activities

The significant environmental influences elicited in the analysis are described here for each affected activity of the ship-to-shore transit operation. Figure 4-1 is a summary outline of the operational analysis (it appears in Appendix B as Fig. B-1; in Appendix B it is divided and expanded into the series of activity analyses described above).

4.1.1 Craft-to-Ship Marriage

The marriage activity is affected by the sea state. As the sea becomes rougher, the craft must exercise more care in maneuvering because of the relative motion between it and the ship. As the sea state worsens, it may be necessary for the ship to maneuver such that it creates a lee harbor for the craft. This creates new difficulties because craft of different sizes and different handling characteristics may be loading from the ship simultaneously. Serious worsening of the sea state may render

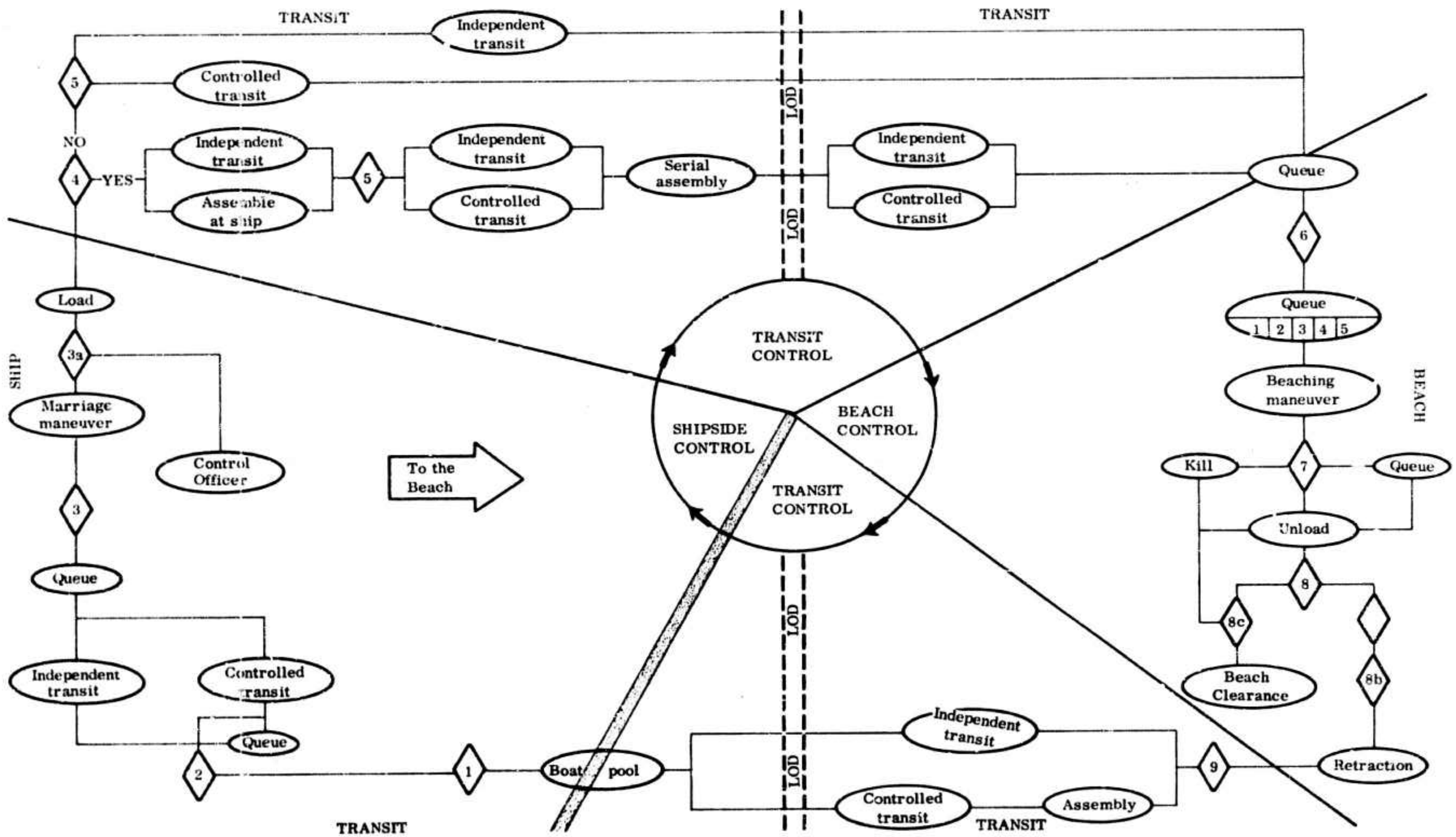

Fig. 4-1. Flow of the Surface Craft Ship-to-Shore Movement

small craft loading impossible, thus forcing the requisition of larger craft to haul high priority cargo that would otherwise have been assigned to the smaller craft.

4.1.2 Ship-to-Craft Cargo Transfer

Sea state is again the critical geophysical factor in cargo transfer activities, but its influence depends both on the type of cargo being transferred (men, vehicles, or logistic supplies) and on the type of craft being loaded. There is a vast difference in handling problems between loading bulk cargo, such as rations, into an LCM-6 using cargo net, and placing a loaded truck into the same type of craft. Further, logistic cargos may have widely varying sizes, weights, and safety handling constraints, giving them greatly differing loading characteristics and thus requiring different craft capacities.

Since the sea state affects craft employment, and cargo loading characteristics affect craft suitability, these effects must be considered together for appropriate craft assignments in order to prevent the development of a queue at the ship because of inefficient loading.

Cargo loading characteristics have been studied intensively at the Stanford Research Institute (SRI) [9]. SRI's extensive definitions of these characteristics assume a nominal environment, and thus do not apply in adverse environmental conditions, but their basic approach to the problem appears compatible with, and would provide support for, the further development of these definitions to include the effects of an adverse environment.

4.1.3 Craft Navigation

The principal adverse effects of the environment on navigation are caused by reductions in visibility. Naval doctrine provides detailed instructions on operating under reduced visibility conditions, whether caused by night or by meteorological conditions. Two standard procedures are prescribed: one confines craft transit to specified boat lanes in order to separate opposing traffic flow; the other requires that the craft transit in groups, in which at least one craft is equipped with navigational equipment (radar and communications) so that navigational assistance can be provided by control ships. Both techniques are standard procedure and are included in crew training, thus minimizing any slow-down caused by reduced visibility. However, when the sea state is adverse as well, and craft assignments become more complex, reduced visibility increases the hazards to craft and the complexity of assignment decisions. Further, the combination of rough seas and reduced visibility may place such restraints on the navigability of small craft that they become essentially inoperable.

4.1.4 Craft Beaching, Unloading, and Retraction

The important environmental condition is surf. The impact of surf conditions is obvious, and methods for negotiating hazardous surf have been, and are, a part of regular training for craft coxswains. When the surf conditions become sufficiently adverse, it is impossible to navigate some craft types. Others, such as the LCM-8 and the LCU can survive in very heavy surf conditions. In the intermediate surf ranges, the smaller craft types are still capable of operations provided there is aid available to them.

Under intermediate surf conditions, extra care must be taken with each landing and, as a condition for such a landing, it may be necessary that salvage craft and heavy equipment from the beach party be standing by to assure a successful operation. This occurs in an actual landing, and any effective simulation must include it. It is especially important that this be simulated for situations in which bulk cargo can be unloaded only at points on the beach where the appropriate cargo handling equipment is available, because the success of the operation requires that every craft land at the right place, at the right time, and remain at that point in a condition to be unloaded—so that the craft is not exposed to the hazards at the beach any longer than absolutely necessary.

When surf conditions are moderate to hazardous, the visibility condition becomes more significant. In order for a coxswain to beach, hold, and retract a craft successfully, he must be able to see the beach line as it relates to the incoming surf lines. A reduction in visibility makes very hazardous the negotiation of moderate surf, which under clear conditions would present no particular problem. The problem becomes more acute at night, when moderate surf and patchy ground fog substantially reduce the efficiency of the operation.

4.2 The STS-2 Simulation Model and its Application

Appendix C describes the STS-2 simulation model and the work done with it under this contract. This work provided the principal basis for the discussion which follows. In summary, the model was analyzed in detail, recommendations were made (and carried out by NWL) for some modifications to STS-2 to assist in this study, and various computer runs (preliminary, production and diagnostic) were made by NWL and analyzed by TRC. This section (4.2) describes some important features of STS-2 relevant to environmental manipulation. To make the analysis and the production and diagnostic computer runs, it was necessary to gather information and to derive from it input data that would relate the behavior of various activities in the operations with changes in environmental parameters. This derivation of input data is covered in Section 4.3. Section 4.4 summarizes our computer runs and results with STS-2.

STS-2 is an event-type model which simulates, on the IBM 7030 (STRETCH) computer, the ship-to-shore movement of a Marine Regimental Landing Team; the surface portion which was used covers the off-loading of the ships to the landing craft, through the movement to the beach, and unloading at the beach, plus all re-cycling until general unloading is complete.

The principal areas in which the simulation appeared to be useful were the ship-to-craft cargo transfer and the craft beaching and unloading.

Because the STS-2 simulation program did not specifically account for the environmental influences of interest, it was necessary to reinterpret the problem in terms of the available simulation parameters.

4.2.1 Cargo Transfer Activity

In STS-2, the simulation of the ship-side activity can be manipulated by varying the following input quantities:

(a) the ship-to-craft transfer or loading rates for troops, vehicles, and other cargo by ship type,

(b) a scale or efficiency factor to vary this rate among ships of the same type,

(c) a lift conversion ratio indicating the number of tons per lift, for ten categories of general cargo,

(d) the number of loading slots available at each ship, and,

(e) the maximum craft queue permitted at each load station.

Of these input quantities, the principal input measure that can be varied to reflect environmental factors is (a) above, the loading rates. The other input data are largely determined by the cargo characteristics and the requirements of the landing force as represented by the scenario of operations ashore. Because the gross transfer (loading) rates are the only inputs effectively available for environmental play, all factors and expected effects to be simulated must be integrated into numerical averages (one each for troops, vehicles and other cargo) which, not unexpectedly, the simulation output simply reproduces. This is because the craft/load scheduling portion of STS-2 does not represent a sufficiently and realistically complex operation to be able to reflect a substantial deviation from the simple procedure of using average values. For instance, in a given computer run, the computation of the prescribed level of selected logistics is taken from the input table, a linear fit of each category is made over the number of hours available to reach this level, and then an attempt is made to send just enough of this category of logistics to the beach so that at the end of the specified time the requirement is exactly fulfilled. Should this chain of events be disrupted for a substantial period of time, the model has no capability of assigning an urgent priority to that category, but simply records the fact that the supply dump ashore has a minus quantity in stock. However, it is known that give-and-take occurs in an actual operation, and that expediting the landing of certain categories of cargo which are temporarily off schedule takes place. If this were not the case, an operation order could schedule the landing of all equipment by specified times, instead of, as it does, scheduling only the initial waves and then setting up general categories for the remainder of the equipment and supplies.

4.2.2 Beaching and Unloading Activity

The simulation of the activity in the beach area is controled through input data representing:

(a) a single set of unloading rates for personnel, vehicles, and other cargo which apply to all beaching craft and ships,

(b) the probability of craft damage, by craft type,

(c) the probability of craft destruction, given damage, by craft type,

(d) the specification of the minimum and maximum values of a rectangular distribution from which damage repair times are drawn,

(e) the specification of the minimum and maximum values of a rectangular distribution from which beach clearance times are drawn,

(f) the number of beach slots provided for unloading personnel, vehicles, and other cargo, and

(g) the set-up or positioning time required for LST unloading.

Difficulties were encountered in attempting to simulate a realistic beach operation with the STS-2 model reflecting varying geophysical effects, for three reasons: (a) unloading rates had to be averaged over all craft types, including LSTs, because the STS-2 model accepts only three input values to represent unloading rates, and these relate to cargo types (troops, vehicles, logistic cargo), not to craft types; (b) the model implicitly assumes that when a craft reaches the beach (pending the availability of a landing slot) it is unloaded immediately; and (c) the model assumes that when craft damage or destruction occurs at the beach, there is a delay (Monte Carlo) in craft salvage, but that there is no delay in unloading of cargo. Even if one assumes that the craft-type unloading-rate averages required by the first limitation [(a) above] can be preconstructed, the remaining limitations [(b) and (c) above] present serious difficulties for arriving at any very definitive conclusions. For instance, the impact of beach congestion might be simulated by restricting the number of available unloading slots, thereby creating a craft queue. However, because the simulation makes no provision for cargo priorities, and unloading proceeds on a first come, first served basis, any analysis to determine when critical items are unloaded at the beach would be rather pointless. The result of this "perfect" cargo salvage operation at the beach largely negates the <u>immediate</u> effect of the damage and destruction probabilities because, regardless of the fate of the craft, the cargo is immediately available at the beach.

Because this is contrary to the real, operational situation, it constitutes an inadequacy in the STS-2 simulation model for the purposes of this study.

The model thus does not reflect: changes in beach-slot availability as a function of craft transit-time delays; delays in craft unload times caused by transit-time delays, or by surf-induced equipment requirements, or by craft attrition; assignment of unloading priorities and subsequent shifts in craft availability; or the cumulative effects of craft unavailability due to attrition, except in extreme cases. Each of these considerations is, or may be, dependent on environmental effects, and inability to reflect them in the model represents inadequacies of uncertain magnitude for the reflection of environmental influences.

4.3 Environmental and Operational Input to STS-2

Study of the ship-to-shore transit operation (see Section 4.1) identified these environmental effects and operations activities: at shipside, the effect of sea state on off-loading time; at the beach, the effect of surf on craft attrition rates, unloading times, and repair and retraction times. The effect of sea state on the rate of advance to the beach, and the effects of precipitation and reduced visibility generally, were also identified but determined unimportant to the study at this point. Later, the effects of reduced visibility were reconsidered in the operational analysis, but as no operational or geophysical data were obtained or used, these effects are not further discussed in this section.

A study of how the simulation model works, and thus, how and to what extent geophysical influences can be reflected in the input variables, is described in Appendix C.

Knowing which environmental effects to consider, and where and how they may be inserted into the model, it was necessary to determine how actual numerical values for these environmental effects can be derived. This is discussed in the following sections.

First, however, a separate study of the environment was undertaken to establish a climatologically and geophysically consistent environment within which to study and manipulate the operation. Visibility, sea state, and surf were considered. Detailed analyses of these and other geophysical factors are documented in the first year's two-volume report [1], with a detailed discussion of the state of the art of their prediction by dynamical and statistical methods, expected future developments in their prediction, and the potential feasibility of their control.

4.3.1 Sea State

Geophysical consistency for sea state and surf can be formulated by using the wind regime as a basis. Wind regime, sea state (wind-waves and swell), and surf have been combined in consistent terms to reduce the possible combinations to manageable numbers. Sea states are described by the historically accepted sea state code [8, 12], which, although today largely supplanted in technical studies by more definitive descriptions [11], is still a useful identifier. Table 4-1 lists the generally accepted sea state code with the corresponding Beaufort wind scale, including dimensions and adjectives. Also included are several typical wave heights calculated by one of the newer techniques [10], from wind velocities.

Table 4-1 necessarily omits much of the additional detail, variability, and complexity which is associated with a true description of ocean waves. However, this simplification was allowed because of the exploratory nature of the work, and in order to render the problem manageable.

It developed that only the upper half of Table 4-1, ending at about Sea-state Code 5, is of interest: at sea states of code values higher, there are no data available relating sea-state effects on off-loading from ships to craft, because off-loading is not attempted under these adverse conditions.

4.3.2 Surf Height

The state of the surf, like sea state, is difficult to categorize in manageable terms. The combinations of factors which affect surf [wind, wind-waves and swell, littoral currents, the physical characteristics of the ocean bottom and shoreline (especially the beach gradient), etc.] can result in a broad and varied spectrum of surf characteristics. The Navy has attacked the problem of describing surf, especially as it affects landing craft, by defining the "Effective Surf Height." This represents the overall effect of breakers, along-shore (littoral) currents, and wind speeds on landing craft or amphibious vehicles in terms of an adjusted breaker height, based on experience. Table 4-2 shows the form used by the Navy for observational purposes.

Because this terminology provides a basic reference point, is well understood and commonly used by personnel associated with amphibious operations, and tends to collapse some of the complexity of surf description, it was adopted for this study.

TABLE 4-1
SEA STATE CODE

Wind			Sea			After G. Neumann [10]	
Speed, (knot)	Description	Beaufort number	Code figure	Description*	Wave height,(ft)	Average height,(ft)	Average height highest 10% (ft)
< 1	Calm	0	0	Mirror-like	0	—	—
1-3	Light air	1	1	Rippled	< 1	0.036	0.075
4-6	Light breeze	2	2	Gentle—slight	1—3	0.18	0.37
7-10	Gentle breeze	3				0.59	1.2
11-16	Moderate breeze	4	3	Light—moderate	3—5	1.8	3.7
17-21	Fresh breeze	5	4	Moderate—rough	5—8	4.25	8.8
22-27	Strong breeze	6	5	Heavy—very rough	8—12	8.2	17
28-33	Near gale	7	6	Very heavy—high	12—20	15	29
34-40	Gale	8				23	47
41-47	Strong gale	9	7	High—very high	20—40	36	72
48-55	Storm	10	8	Very high—mountainous	40	52	104
56-66	Violent storm	11	9	Exceptionally high sea	—	73	147
> 66	Hurricane	12				(> 75)	(> 147)

*Two adjectives given for one category represent slight discrepancies among different source references.

TABLE 4-2
EFFECTIVE SURF CALCULATION

Date/Time________

The effective surf represents the overall effect of breakers, longshore current and wind speed on landing craft or amphibian vehicles in terms of an adjusted breaker height. This calculation is made using values from the SUROB report, and substituting as follows:

ITEM	SUROB	ADJUSTMENT		CALCULATION
CHARLIE (Breaker period)	______	Over 16 seconds, subtract one foot	-1	
		11-16 seconds, no change	0	__________
		Below 11 seconds, add one foot	+1	
DELTA (Breaker type)	______	80-100% spilling, subtract one foot	-1	
		21-69 % plunging, no change	0	__________
		70-100% plunging, add one foot	+1	
ECHO (Breaker angle)	______	4°R to 4°L, no change	0	
		5° - 9° angle, add one foot	+1	__________
		Over 9° angle, add two feet	+2	
USE WHICHEVER ADJUSTMENT VALUE IS GREATER, ECHO OR FOXTROT				
FOXTROT (Longshore current)	______	0 - 0.9 knots, no change	0	
		1.0 - 2.4 knots, add one foot	+1	__________
		2.5 - 3.9, add speed minus one	--	
HOTEL (Wind speed)	______	0 - 20 knots, no change	0	
		21 - 25 knots, add one foot	+1	__________
		26 - 30 knots, add two feet, etc. (i.e., add one foot for each 5 knots over 20)	+2	

(ALFA)________________ + (TOTAL)______________ = ______________
(Significant breaker height) (Adjustment Calculations) (Effective Surf)

MAXIMUM RECOMMENDED SURF HEIGHTS

Boating - Maximum surf heights for use of boats in exercise conditions are expressed as follows (COMPHIBLANT INST 03840.1C):

CRAFT/VEHICLE	MAXIMUM BREAKER (FT)	MAXIMUM SURF (FT)
LVTP 5	10*	10*
Warping Tug (Pontoon)	7	8
LCU	7	8
CAUSEWAY (3 x 15)	7	7
LCM-8	7	7
LCM-6	6	[illegible]
LVT (R)	6	6
LCVP	5	5
DUKW	5	5

*When 3 or less lines of breakers are present, otherwise 8 feet.

4.3.3 Environmental Effects

As the study proceeded, it became evident, as a result of extensive investigation (see Appendix D), that the only recorded data on the quantitative relationship between the operational parameters and environmental factors of interest for the craft of concern were that for the so-called "nominal" state, which connotes a benign environment. Some "rules" are available for the maximum acceptable surf height (Table 4-2), but without quantification of what to expect under those conditions. As data for an adverse environment were indispensable for this project, it was essential to expend a portion of the study effort interviewing experienced Naval and Marine Corps personnel in order to acquire enough data to permit continuation of the study.

It must be emphasized at the outset that the information gained is only a sample resulting from an extensive, but not exhaustive, search; it represents real experience of knowledgeable personnel, but the extent to which it represents the total spectrum of such data is not known. In addition, in order to solicit meaningful responses from the interviewees, it was necessary to attach specifications in some detail to the environmental and topographic conditions of interest, with a consequent limitation on the breadth of applicability of the answers obtained.

Specific data were obtained in two major areas: the effect of adverse sea state on times for loading various landing craft at shipside, and the effect of adverse surf on the ability of craft to negotiate surf, unload and retract. More than twenty Naval and Marine Corps officers were interviewed in groups at the U.S. Naval Amphibious Base, Little Creek, Virginia (see Appendix D). Included were officers with varying experience, representing Naval Beach Groups, Amphibious Groups, Amphibious Craft Units, Beachmaster Units, the Naval Amphibious School, and the Marine Corps Landing Force Training Unit. The procedure was to define the general problem and to focus attention on the specific operational event, describing what was wanted in terms of the wind and sea state or surf conditions of interest, together with as specific a characterization of the environmental condition of concern as possible. The subsequent discussions, elaboration, and, to some extent, interchange among the interviewees resulted in a mass of notes and memoranda which were later compiled, interrelated, and reduced to single values applicable as inputs to the STS-2 simulation model. These are shown in Tables 4-3 for loading rates and 4-4 for surf effects. Finally, because the model essentially plays loading rates only for LCMs and LCUs*, and plays them by ship type and load type only, it was necessary to make an ultimate combination of the values in Table 4-3 into the final Table 4-5 which, with Table 4-4, gives the actual simulation inputs.

4.3.4 Summary of STS-2 Input

The following summarizes the operational input values for the STS-2 simulation. The inputs for each run were set up in tabular form as shown in Table 4-6. The basic conditions for each run are set by the first three entries [(a), (b), and (c)] in the table.

Descriptions for each entry on the sample input data sheet, Table 4-6, are:

(a) Run number—an arbitrary number used for ease of reference to the several different computer runs.

(b) Sea state—refers to Table 4-1, which defines, among other factors, the maximum distance between the crest of a wave to the bottom of the trough between waves.

(c) Surf height—refers to Table 4-2, which describes the way in which effective surf height is calculated. The value governs entries (h) and (j). Three entries were used in surf height: 1c, 5c, and 5o. The figure 1 or 5 refers to the effective height in feet. The subscript "c" or "o" refers to the assumed proficiency of the landing craft crew as described in Table 4-4. The "c" represents the "current" proficiency of the crews in peacetime, i.e., generally not thoroughly skilled at operating and landing the craft; "o" on the other hand is an "optimum" operating proficiency, which would be the case if the crews were operating regularly as in wartime, with consequent increase in skill. This concept was suggested by the amphibious personnel at Little Creek (Appendix D).

(d) Loading time (by ship type)—All ships are played as having equal loading rates. The loading rates for troops, vehicles, and logistics are averages which are weighted by the number of each type of landing craft

*LCVPs and LVTPs are pre-loaded; thus, loading time for these craft is of no concern here.

TABLE 4-3
LOADING RATES* (SHIP TO LANDING CRAFT†)

Sea State	LCM-6			LCM-8			LCU		
	Troops	Vehicles	Logistics	Troops	Vehicles	Logistics	Troops	Vehicles	Logistics
0	33	11.9	4.5	33	11.1	4.5	17	7.2	2.2
1	33	11.9	4.5	33	11.1	4.5	17	7.2	2.2
2	33	11.9	4.5	33	11.1	4.5	17	7.2	2.2
3	33	11.9	4.5	33	11.1	4.5	17	7.2	2.2
3-1/2‡	33	11.9	4.5	33	11.1	4.5	17	7.2	2.2
4	41.4	14.4	5.1	33	11.1	4.5	17	7.2	2.2
4-1/2‡	53.3	16.9	6.9	44.2	16.1	6.9	17	7.2	2.2
5	66.0	23.8	9.0	66	22.2	9.0	14.4	14.4	4.4

*Troops: minutes per 100 men; Vehicles: minutes per vehicle; Logistics: minutes per ton.

†Although LCVPs and LVTPs are played in the STS-2 simulation, they are played as being pre-loaded, so that changes in loading time due to sea are not admissible.

‡These interpolations in the standard sea state code were inserted by us to permit finer definition of sea state, and thus more gradual worsening of sea state conditions from one simulation run to another (Appendix C).

TABLE 4-4
SURF EFFECTS ON LANDING CRAFT*

Effective surf height (ft)	LCVP						LCM-6					
	Current† capability			Optimum† capability			Current capability			Optimum capability		
	D‡	K¶	R§	D	K	R	D	K	R	D	K	R
1	.05	0	8/10	.05	0	8/10	.10	0	10/10	0	0	1/2
2	.15	0	11/15	.05	0	8/10	.10	0	10/10	0	0	1/2
3	.18	.10	11/18	.10	.10	8/11	.10	0	10/10	0	0	1/2
4	.55	.75	15/25	.30	.50	10/15	.40	0	11/20	.05	0	8/10
5	.70	.80	20/40	.50	.60	15/25	.55	.05	15/28	.10	.01	15/20
6	1.0	1.0		.80	1.0		.70	.15	25/40	.35	.05	15/20
7				.90			.80	.20	32/50	.40	.07	15/25
8				1.0			4.0	?	45/?	.50	.10	15/?
9												
10												
11												

*LCM-8 and LCU not included here because no information available; they rarely experience difficulty even in 8 ft effective surf; higher surf not within experience of PhibLant personnel queried in this study.

†"Current" capability refers to the skill and experience of craft coxswains at present (nominally peacetime). "Optimum" capability refers to the improved skill which would be expected with wartime experience, as was found to be the case in WW II. The "current" and "optimum" concepts were suggested by experienced amphibious officers in discussions of landing craft characteristics (see Appendix D).

‡D = Probability that craft encounters difficulty.

¶K = Probability of kill (loss to operation), given that craft encounters difficulty.

§R = Minimum/maximum time (minutes craft is delayed in repair and retraction, given that craft encounters difficulty.

TABLE 4-5
LOADING TIME (minutes*)

Sea state	Troops	Vehicles	Logistics
0	31	12	4
1	31	12	4
2	31	12	4
3	31	12	4
3-1/2	31	12	4
4	36	13	5
4-1/2	47	15	6
5	61	22	8

*Troops: minutes per 100 men
Vehicles: minutes per vehicle
Logistics: minutes per ton

expected to be played in the game. The loading rate table (4-3) shows how the loading rate varies both with sea state according to the three types of craft which are being used (LCM-6, LCM-8, LCU) and during selective and general unloading. The loading rate table shows a range in time, according to the type of item being loaded (troops, vehicles, or logistics) by craft type and by sea state. The time range had to be reduced to a single number (see Table 4-5). The figures used in the Stanford Research Institute (SRI) MARADS system [9] for loading rates of troops and logistics were considered in this study as well, and the weighted averages used were supported by calculations from that source. The loading time per square foot (used to figure loading time for vehicles) was multiplied by the weighted average of square feet per vehicle, listed in the serials of the administration plan used in this study, to arrive at a figure for minutes to load each vehicle under normal conditions of sea and surf. Each craft was treated according to its sensitivity to sea state; consequently, nominal conditions for the LCU, as an example, are not nominal, in some categories, for the LCM-6.

TABLE 4-6

OPERATIONAL INPUT FORMAT FOR THE STS-2 SIMULATION

(a) Run Number_______

(b) Sea State_______

(c) Surf height (ft)_______

(d) Loading Time (by ship type)

				Ship Type
				min/100 troops
				min/vehicle
				min/lift

(e) Unloading Time

_______min/100 troops

_______min/10 vehicles

_______min/10 lifts

(f) Maximum Queue _______(at load station)

(g) Craft Characteristics:

average speed								(knots)
capacity								(short tons)
square ratio								(LCVP = 1)

(h) Attrition Probability:

damage seaward of LOD							
sunk seaward of LOD							
damage LOD to beach							
sunk LOD to beach							
damage on beach							
destroyed on beach							

(i) Lift Conversion:

category 1 _________ton/lift

category 2 _________ton/lift

category 3 _________ton/lift

category 4 _________ton/lift

category 5 _________ton/lift

category 6 _________ton/lift

category 7 _________ton/lift

category 8 _________ton/lift

category 9 _________ton/lift

category 10_________ton/lift

(j) Repair Time for Surface Craft:

minimum_______min

maximum_______min

(k) Beach Status

unloading spaces available

personnel_________

vehicles _________

logistics _________

LST _________

(l) Time required for LST to prepare to unload at beach or causeway _____min

(m) Delay time to clear craft destroyed on beach

minimum_______min

maximum_______min

(n) Ship number_______scale factor_______

Ship number_______scale factor_______

Ship number_______scale factor_______

Ship number_______scale factor_______

Ship number_______scale factor_______

(e) Unloading time —These numbers are averages of unloading times used in the SRI MARADS system, weighted by the number of each type of landing craft used.

(f) Maximum queue (at load station)—Initially, the number used for maximum queue was to be unity, to insure that landing craft would not be assigned in excess of loading needs—which would create the possibility of a shortage of available craft in the boat pool. Four partial runs (runs which did not play the general unloading part of the operation) were made to determine how much influence this maximum craft queue had on the time from the start of the game until the time to start general unloading (see Appendix C). A maximum craft queue of four provided the shortest time; that value was chosen to be used in the production runs.

(g) Craft characteristics—Average speed and capacity figures were taken from Naval manuals. The square ratio, which describes the useable square footage of landing craft, is taken from previous STS-2 runs.

(h) Attrition probability—Probabilities in this table are dependent on surf height and type of craft as given in Table 4-4. The values for these probabilities were established as described earlier (Section 4.3.3). Attrition due to environmental conditions was significant only in surf, so that attrition at sea was not played.

(i) Lift conversion—These are judgmental values which resulted from discussions with Naval personnel.

(j) Repair time for surface craft—These values were originally much higher in runs made prior to this study (Appendix C); later technical discussions with Naval personnal resulted in the change of the maximum and repair times from 180 minutes and 60 minutes to a range of values of 10—35 minutes and 9—18 minutes, respectively. The actual value played depends upon the entry under Surf height (Table 4-4).

(k) Beach status—The number of unloading slots at a beach is prescribed by military personnel concerned with the simulation of the operations.

(l) Time required for LST to prepare to unload at beach or causeway—This value is taken from runs done by NWL prior to our study.

(m) Delay time to clear craft sunk at beach—Naval personnel have stated that the values used here are representative of the activity. These values are not varied in the play.

(n) Ship scale factor—is taken from runs done by NWL prior to our study.

4.4 Results of the Use of STS-2 Model

The use of the STS-2 simulation model in this study is described in some detail in Appendix C. This section summarizes that appendix.

Three sets of computer runs were carried out: preliminary, production, and diagnostic.

Preliminary runs were made to obtain the necessary data for an evaluation of the model's basic operating characteristics. Model parameters were exercised over a wide range of values. Analysis of the runs identified several difficulties: (a) the preliminary runs reflected only a part of the surface portion of the Regimental Landing Team ship-to-shore movement, which was insufficient in operational scope for our purposes, and (b) the timing of the operation was atypical in respect to allowed delay before general unloading was started. As a result, NWL personnel made substantial adjustments to the basic input information, thus resolving the problem of scope. The problem of timing required considerable study. First, LST operations were excluded because of the fact that LSTs are pre-loaded, which differs greatly from the other craft, and thus distorts the over-all landing times. Then, because the pace of requirements ashore for vehicles, men, and logistics were neither particularly demanding nor very realistic*, more preliminary runs were made in which unloading-time requirements were made progressively more stringent. Also, at NWL's suggestion, the number of craft allowed to queue at shipside, which was originally one, was varied to four, five, and six to determine the most efficient number: the optimum "landing craft

*In the opinion of Navy personnel with amphibious experience (see Appendixes C and D).

queue" is four. Further runs were made to discover the reasons for some anomalous landing times in runs in which craft queues were varied: one (run 610) showed that competition for loading, between serials and logistics, was causing delays. Further, to explore the potential of these runs for environmental manipulation, run 612 was conducted as a replicate of run 610, but in an adverse environment; this demonstrated, among other things, that worsening sea state was reflected in the landing times as a simple additive function of the increased loading times for each craft. Thus, except for serials located in holds where competition for loading would occur, the simulation aspect of the model is in essence a bookkeeping operation.

The twelve production runs consisted of progressive steps from a nominal to an adverse sea state, in four stages. The three runs in each stage comprised one with benign surf height and two with adverse surf height; the latter two differed in the degree of proficiency assumed for the landing craft crews. One of these runs (run 710) was replicated three times to examine the effect of attrition rates (determined in the simulation model by random number selection), but the results were the same for all three runs. The effect of the increasingly adverse sea state is to cause increases in shipside craft-loading times, and the effective surf height is reflected both in the craft attrition probabilities at the beach and in the craft repair times. The intent of these runs was to discover the point at which environmental change had a noticeable effect on the over-all operation. Instead of generating results which could be interpreted in these terms, the results of the production runs raised further questions, which necessitated the carrying out of diagnostic runs.

The diagnostic runs were made to determine the extent to which competition among serials, and between serials and logistics, for loading facilities at shipside was affecting the time to complete the unloading of non-scheduled serials, which was to be one of the important measures of environmental sensitivity. In order to provide material for diagnosis, these runs did not play any general unloading, and half of them did not play any prescribed logistics, for comparison. Study of the results of the diagnostic runs combined with the production runs revealed two basic problems (no unloading times played for serialized logistic loads or floating dumps, and a sporadic error in the treatment of load and unload times for craft carrying logistics). Because of this qualification (discussed in detail in Appendix C, Section C.6), the numerical results of these runs are unreliable*.

If, however, one were to accept the output of the model without question, the conclusion would be that as the sea state grows more adverse, the time that the non-scheduled serials arrive at the shore is delayed; increasing surf height merely increases craft attrition statistics, with no important effect on the operation. The output would further indicate that the factor that determines the time that a given category of serials arrives at the shore is whether there is competition for the craft-loading facilities at shipside. However, these findings, as stated, are not in agreement with observations, as described to us by amphibious personnel listed in Appendix D. The importance of competition for craft loading facilities in a real operation can be minimized by assigning priorities as needs arise. The time a serial arrives at the beach would, in reality, also be varied by the craft attrition rate, because of delays caused by broaching or repairs. These delays are not reflected in the simulation in the time that the non-scheduled serials are landed on the beach.

In conclusion, it may be said that much was learned in the manipulations of STS-2, but that the model was not especially suited to environmental study.

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*NWL made the necessary corrections and offered replacement computer runs, but limitations on time and resources for analysis prevented our taking advantage of the offer.

5.0 FINDINGS

The previous sections of this report have shown how the large-scale problem of defining where, how, and how much the environment affects Naval and Marine operations has been attacked and studied, and how some facets of the problem have been followed through to tentative conclusions. While no definitive quantitative measures of environmental impacts have resulted, the steps taken in that direction have been productive both by demonstrating how the quantitative measures can be derived, and by identifying the sources and resources that should be developed and exploited.

This section summarizes the research, rationale, and justifications for pursuing the use of simulation and, further, suggests a detailed plan for extending and, possibly, concluding the major course of study up to the point of identifying those geophysical factors that would yield the most immediate and most profitable returns for a concentrated study to improve their prediction, modification, or control.

Although the findings are couched in terms applicable to the amphibious case studied, it is considered that they are generally applicable to any operational simulation.

5.1 STS-2

The original commitment to study simulation as the only and best means to derive the quantitative values of environmental impact, and the need to create other methodologies for the same purpose, were discussed in Sections 1.0 and 2.0. The analyses of, and with, the STS-2 simulation model (Sections 4.2, 4.3, 4.4 and Appendix C) have shown this model inadequate for the purposes of the long-range study, because it does not simulate directly and quantitatively the environmental factors known to affect the operation, and because it is not sufficiently complex to handle simultaneously the changing conditions of the environment, the changing on-shore battle-inflicted demands for supplies, the perturbations of small-scale operational decisions, and the second- and third-order effects of craft attrition. While these considerations are included conceptually in STS-2, they are not included in its design because STS-2 was intended for purposes quite different from those of this study. It will be shown that all these considerations should be accommodated in a more comprehensive simulation model. Further, because of the stringency of the demands listed above, and described more fully below, the development of a new and more comprehensive simulation model should be considered; however, because of the anticipated magnitude of resource expenditures involved, consideration of another alternative, i.e., the creation of methodologies other than complex computer simulation, should also be considered.

5.2 The Need for a New Simulation Model

It is evident that analyses and/or simulations of an operation in its environmental setting have not previously been undertaken in any appreciable depth.

This situation contrasts markedly with the interested and responsive attitude found among the operating personnel, and others concerned with the analysis of Naval operations, who were interviewed in the course of this study (see Appendix D); these personnel in general recognized the value of environmental analysis and gave willingly of their time and information to further the present limited effort.

A simulation model which would provide the capabilities discussed above would allow an attempt to be made to define sensitive areas of the operation where environmental control should be considered. It would further provide for the assessment of the degree of environmental control necessary to provide a defined incremental increase in the probability of mission success. Further, the significance of such a model would go far beyond that of the assessment of environmental factors alone. Such a model's contributions to tactics, equipment design, and cost/effectiveness assessments could be extensive and important. Of course, the cost and time required to generate such a model would also be large, and the effort would require the cooperation of many organizations within the Navy working in close concert. Therefore, it is important to know what requirements the model should fulfill, how those requirements would be fulfilled, and what might be expected from this simulation model. These considerations are shown by this study.

5.3 Requirements of a New Simulation Model

The outstanding control aspects of a military operation are planning, flexibility, and the experience, understanding, and initiative represented by the command structure. The complexity of any of these aspects is probably much greater than is commonly appreciated. This complexity makes demands which are undoubtedly greater than can be met by an even more comprehensive simulation model than those examined in this study. Yet a simulation model, not necessarily intended for, or applicable to, the obviating or circumventing of any of the complexities, but designed to anticipate them, in order to determine the effects of environmental impingement on the operations, can (at least theoretically) be conceived and created because, fundamentally, the operational decisions and their proximate and more remote consequences are rational and logical. Whether such a simulation model is feasible remains for further consideration. The demands in such a simulation model are discussed below.

For a military operation to meet the impact of substantial environmental changes (as well as operational and tactical changes) requires, in most cases, not simply a change in the directly affected portions, but in portions of the operation not directly affected as well. The critical nature of the flexibility to coordinate and allocate resources, built into the operation to meet just such contingencies, is both the hallmark of the military operation and the principle reason that the simulation approach to sensitivity analysis has been found necessary. Thus, the first demand upon a comprehensive simulation model is that it have the complexity to trace the proximate and the remote consequences of small-scale operational decisions.

Extensive, highly-detailed planning is required for an operation to achieve the capability described above; this planning is characteristic of military operations. However, in addition, a high degree of flexibility and initiative is required of force personnel. This character of the military operation makes the construction of an adequate simulation model even more difficult, because the kinds and amounts of information available to the field officers, information that may range from statistical source material to personal judgement and intuition, would be difficult to duplicate in the simulation. However, it should be possible to simulate this anticipation/reaction capability in good approximation (to the extent required to obtain a definitive sensitivity analysis) because this capacity is, at bottom, rational and logical. Thus, the second major demand upon the simulation is that it approximates, to some realistic extent, the rationale and logic of operational decisions.

The two major demands detailed above are further complicated by the fact that decisions made in response to operational and tactical changes compete with decisions made in response to environmental changes, and that choices are made and actions are taken according to the resolution of these conflicting considerations. A viable course of action is the result of compromising between what must be done and what can be done. Thus, a realistic simulation must be able to integrate operational and environmental considerations into a single logical structure, as, indeed, the field officers must.

Finally, because operations plans include unallocated resources, such as the on-call, non-scheduled floating dump and general unloading categories, there is by definition uncertainty concerning the exact order and time of landing of these components. Therefore, further complicating the demands on a simulation model is the inappropriateness of attempting to evaluate environmental sensitivity without considering a large variety of tactical situations encountered by the forces, situations which have the effect of generating varying requirements for operational decisions. The fourth major demand on a simulation model is that it include some generation of specific sequences of requirements to properly evaluate sensitivity under a variety of sequences of operations within the general plan.

That the four major demands on a comprehensive simulation model described above can be met is implied by two significant considerations: first, that the subjectivity of certain kinds of field command decisions are ultimately based on logical and rational relationships among changing operational and environmental conditions, and thus can be reasonably approximated and anticipated by a simulation model; and second, that in spite of the multi-faceted complexity of competing environmental, tactical, and operational considerations, their interdependent responses to changing external conditions are also logical and functional. The limiting constraint imposed by this latter consideration, indeed, the constraint that will probably determine whether such a simulation model is feasible, is that, in order to integrate functionally the possible mixes of environmental, operational, and tactical conditions, the simulation must map all of the possible or reasonably anticipated conditions in each of those three realms; that is, the simulation should be of broader scope than any one or several environment-operation-tactics configurations.

An important additional finding, independent of those discussed above, and arrived at largely by the inference of the investigators on this project as a result of their total assimilation of information in the course of this work,is discussed below. This finding cannot be substantively documented, but rather is a judgemental combination of the analyses of the ship-to-shore operation, manipulation of the STS-2 simulation model, and the extensive interviews with operations personnel; it is to the effect that the flexibility and resources of an operation, combined with the initiative and experience of the personnel, provide an inherent capability for the operation as a whole to adapt to a worsening environment to a significant degree, and probably to a degree that is not generally recognized. However, at some point the capacity for adaptation is exhausted and the operation suddenly becomes critically sensitive to the environment. It is considered important to explore this concept by means of a proper simulation, the only presently known means for such exploration.

5.4 Data Requirements

Aside from the technological and hardware limitations on the design of such a model, there are software requirements, both for input information and for applicable methodologies to acquire the input information. The required input information and the means to acquire it, as determined in this analysis study, are discussed below.

In considering the following discussion of required input information, it should be borne in mind that it is the intent of this study to evaluate the use of simulation for determining quantitatively the value of pursuing improved prediction, modification, or control of geophysical factors for military applications, and thus for identifying the geophysical factors that would yield most immediate and most profitable returns; and then to spell out what is needed for such a simulation. Thus the over-all, quantitative impacts of various phenomena, and not the proximate effects on small-scale operations activities, make up the principal subject for consideration. However, a simulation model that will compute these quantitative values of the overall impact of various geophysical phenomena must include, first, identification of the impact points, and second, quantitative measures at those impact points of both environmental changes and their immediate effects.

5.4.1 Environmental Impact Points

The identification of environmental impacts points requires detailed small-scale descriptions of operations activities and a highly-refined inventory of geophysical factors that may affect military operations. The method for describing operations activities in detail has been discussed in Section 4.0 and demonstrated in Appendix B of this report. An inventory of geophysical factors has been documented in the final report for 1964 [1] along with an assessment of the present and near-future possibilities for their improved prediction, modification or control.

5.4.2 Quantitative Values for Environmental Change and its Operational Impact

Because a simulation model employs only quantitative values, and because the goal of simulation is the generation of other quantitative values, the input values must be described in that same fashion for both the variations in environmental conditions and the effects that these variations have on the progress of the operations being studied.

Quantitative descriptions of environmental conditions have been devised by many persons and agencies for specific purposes in specialized areas of concern; some of these quantifications are relevant and useful in the simulation considered here. Other quantitative measures of the environment have yet to be derived. A significant need exists for a search and compilation of this information. The data required to define and support this simulation effort must be of the micro-variety, that is, fragmented to fit the model structure. However, the experience gained in the attempt to find data for input to the simulations using STS-2 (see Appendixes C and D) indicates that the data that can be collected are fragmented in just this way and that the relationships are only definable on this level of detail. Additional confirmation (Appendix D) of this fact was obtained from a review of a number of amphibious exercise reports, which in many instances cite examples of conditions that have arisen unexpectedly and that generally have caused the operation to be delayed or terminated due to the danger to lives and equipment. In cases such as this, a valuable residue of experience is left with those personnel on the spot. Just such experiences as these are the building blocks needed to collect and extend the information into operational environments which may be faced in an emergency, but which, for very good reasons, cannot be attempted on a training basis. Each exercise such as this corresponds in a sense to one replication of a large-scale realistic computer simulation with a specified set of inputs. As such, of course, the degree to which it can provide quantitative descriptions of the requisite inputs is quite limited.

A workable but incomplete example of the kinds of information that are needed was compiled for this study (see Section 4.3). The sources for that information are listed in Appendix D.

Quantification of the direct impact of changing environmental conditions on operations activities is a far more difficult problem. The search for the requisite detailed quantitative relationships between the affected individual sub-components of the operation and the relevant environmental parameters revealed that, although these data exist in fragmented form (scattered through various documents, or in the knowledge and experience of personnel of the operating forces; see Section 4.0), they could only become useable in this and other studies as a result of an organized and intensive collecting activity. This statement is undoubtedly true for most, if not all, Naval operations. The effort devoted to the task of data gathering in this study revealed the disorganized state of the information, and, although successful in accumulating a sample of such data for this study (see Section 4.3), and in demonstrating how it could be done (see Appendix C), was extremely limited in extent. The need for such data in these studies is obvious; further, as a result of TRC support of work in fleet command and control systems under NAVCOSSACT*, it is also evident that a major requirement for these kinds of data exists in the important field of command and control, and probably in other fields as well.

5.5 Potential Value of Simulation

That military operations are sensitive to the environment is undoubtedly true; however, it is critical to define that point in the spectrum of possible environments where the flexibility and resources of an available force are exhausted and the mission is in jeopardy. At that point, even a marginal ability to control some portion of the environment may mean the difference between success and failure, or, what is more likely, that the forces at hand will be able to cope with a situation which would normally be beyond their capacity. Since any effort expended to provide environmental control techniques could not be expected to yield a capability for total control, but rather, an ability to modify environmental conditions to a greater or lesser degree depending on the situation, it is mandatory that those areas of application providing the maximum mission enhancement be defined. That simulation is a proper methodology (perhaps <u>the</u> proper methodology) to provide a solution to the problem has been reinforced by this study.

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6.0 CONCLUSIONS

6.1 Simulation

It is concluded, based on the findings of this study (Section 5.0), that it is feasible to conduct a definitive and quantitative evaluation of the environmental sensitivity of Naval operations, as exemplified by the amphibious operation. Simulation is, at present, the only methodology considered practicable for environmental analysis of complex operations (see Section 2.1). Therefore, the use of an adequate simulation model, developed along the guidelines of this report, can be expected to produce findings that will make valuable contributions to the fields of naval research, development, and operations (see Section 5.2). However, adequate operational analysis, synthesis of the simulation, acquisition of operational data, and the study itself (using the simulation) would be a major project for each operation of interest, far exceeding in effort any considered to date, and would importantly involve the Naval arms appropriate to each operation simulated.

Although it was not possible (in this study) to establish definitively the quantitative dependence of the amphibious operation on its environment (see Section 4.2), the study has indicated (Section 5.3), an important qualitative property of the operation which may well be applicable to other major and complex Naval operations as well, namely, that the flexibility and resources of the operation, combined with the inititive and experience of the personnel, provide an inherent capability for the operation as a whole to adapt to a worsening environment to a significant degree (and probably to a degree that is not generally recognized); however, at some point this capacity for adaptation is exhausted and the operation suddenly becomes critically sensitive to the environment. This latter point deserves further consideration: the critical sensitivity of the operation to the environment may result both from prolonged exposure to a fairly constant adverse environment, with its cumulative effects, or from sudden or severe changes in one or more of the relevant geophysical factors. Thus, quantitative assessment of geophysical effects remains crucial both for determining the cumulative effects of adverse conditions on an operation and the increasing susceptibility of the operation to reversal or failure because of environmental change.

6.2 Data

A major data gap exists for quantitative relationships between activities within Naval operations on the one hand and the geophysical factors that may affect them on the other (see especially Section 5.4.2); these data are prerequisite to the evaluation of environmental influences on many important Navy activities.

7.0 RECOMMENDATIONS

Based on the foregoing findings and conclusions, it is recommended that:

1. analysis of the environmental sensitivity of naval operations be continued and expanded employing the concept of simulation (see Section 6.1),

2. research be undertaken leading to the generation of new techniques (other than simulation) for analysis of the environmental sensitivity of naval operations (see Sections 1.0, 5.1, 5.5, 6.1),

3. work be initiated to seek out, collect and collate data on the quantitative relationships between activities within naval operations and the relevant environmental parameters (see Section 6.2).

8.0 REFERENCES

1. Brooks, D. L., G. R. Hilst, and G. H. Milly, 1964: Geophysics in Warfare(U), Vols. I and II, Final report 7662-119S and 7662-119C, Contract Nonr 4112(00). The Travelers Research Center, Inc. Volume I, SECRET; Volume II, CONFIDENTIAL.

2. Dept. of the Army and the Navy, 1962: Doctrine for Amphibious Operations, Report NWP 22(A), July.

3. Dept. of the Navy, 1961: The Amphibious Task Force Plan, Report NWIP 22-1(A), August. CONFIDENTIAL.

4. —, 1960: Naval Gunfire Support in Amphibious Operations, Report NWIP 22-2, March. CONFIDENTIAL.

5. —, 1963: Employment of Aviation in Amphibious Operations, Report NWIP 22-3(A), February.

6. —, 1962: The Naval Beach Group, Report NWIP 22-5, July.

7. —, 1962: Ship-to-shore Movement, Report NWIP 22-6(A), February.

8. Dietrick, Günter, 1963: General Oceanography, Interscience Publishers, New York.

9. Dixon, H. L., D. A. D'Esopo, and B. Lefkowitz, 1963: An Amphibious Deployment Simulation Model: The MARADS System, Report NWRC RM19, Naval Warfare Research Center, Stanford Research Institute, Menlo Park, California.

10. Neuman, G., 1952: On Wind Generated Waves with Special Reference to the Problems of Wave Forecasting, ONR Contract Nonr-285(05). New York Univ., Coll. of Engineering, Dept. of Meteorol. and Oceanog., New York.

11. Pierson, W. J., G. Newman, and R. W. James, 1955: Observing and Forecasting Ocean Waves, H. O. Publ. 603. U.S. Navy Hydrographic Office.

12. Williams, J., 1962: Oceanography, Little, Brown and Company, Boston.

APPENDIX A

SELECTION OF A SINGLE MISSION ACTIVITY FOR ANALYSIS OF GEOPHYSICAL SENSITIVITY

by

George H. Milly

APPENDIX A. SELECTION OF A SINGLE MISSION ACTIVITY FOR ANALYSIS OF GEOPHYSICAL SENSITIVITY

It was apparent at the outset that only a very few missions could be studied in detail to achieve a quantitative definition of sensitivity to geophysical factors through mission simulation. The rationale for selecting these missions—and ultimately, the one mission, amphibious operations—is discussed here.

The total inventory of military missions, as listed for the first year's study*, is in Table A-1. Of these missions, those with negligible dependency* on geophysical factors were eliminated first. Then, missions that could be considered constituents of larger missions were eliminated. The remaining missions are shown in Table A-2, with synopses of important functions within each mission

These missions (Table A-2) were then ranked in order of their sensitivities to the influences of geophysical factors-in accordance with the number of geophysical factors involved, not the degree or extent of sensitivity. Mission sensitivity is defined as either enhancement or curtailment of mission effectiveness through improved prediction, modification, or control of the geophysical factor being considered. The fourteen missions in Table A-2 were ranked twice: once against the complete list† of geophysical factors evaluated in the first year's study* and once against the four‡ geophysical factors determined to have the greatest potential for future exploitation through improved prediction, modification, or control* (see Table A-3). Either way, missions 1 and 12 headed the lists, and the next five missions were approximately the same on both lists. Table A-4 ranks the fourteen missions in their order of sensitivity to all geophysical factors (from Table A-3).

The fourteen missions were tabulated with the geophysical factors and their associated warfare concepts, the purpose for which the geophysical factor would be exploited, and the specific mission functions that are affected (see Table A-5).

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*Brooks, D. L., G. R. Hilst, and G. H. Milly, 1964: Geophysics in Warfare (U), Vols. I and II. Final report 7662-195 and 7662-119 C. Contract Nonr 4112(00). The Travelers Research Center, Inc. Volume I, SECRET; Volume II, CONFIDENTIAL.

†Clouds, thunderstorms, hurricanes, fog, electro-magnetic propagation, surface stability, underwater sound transmission, magnetic anomaly, storm surges, earthquakes, tsunami.

‡Clouds, thunderstorms, hurricanes, fog.

In Table A-5, the missions are listed in the first column, in the order of their sensitivity to geophysical factors. Opposite each mission, in the second column, is a list of geophysical factors: in the third column is the warfare concept or purpose of conjoining the preceding mission and geophysical factor. The fourth column shows the relevant employment of the geophysical factor; whether for mission enhancement (E) by either prediction (P) or control (C), or as a weapon (W) itself by prediction (P) or control (C). Column five shows the particular functions within a mission affected by exploitation of the geophysical factor.

Then, by considering mission functions alone, it was possible to list the missons in function groups according to the kinds and numbers of functions they have in common (see Table A-6). The four mission-function groups were then analyzed independently (see Tables A-7, a—d) to redetermine the pertinent geophysical factors, their modes of employment, and the mission functions and systems that they affect.

It now becomes apparent, by examining Tables A-6 and A-7, that mission 12, amphibious operations, more than fulfills all the requirements previously discussed: i.e., mission 12 is sufficiently large and detailed that the propagation of a geophysical influence through the system could be traced to assess its ramifications and the potential benefit of its improved prediction, modification or control; it exhibits dependency on each of the geophysical factors determined* most susceptible to improved prediction, modification, or control; and a simulation program was available that could be modified appropriately for an examination of the interactions between mission functions and geophysical factors.

*_Op. cit._

TABLE A-1
TOTAL LIST OF MISSIONS CONSIDERED

Conventional War Missions (Third Area)

1.* strengthening will to resist
2. mobile platform for air operations
3.* long range reconnaissance
4. show of force
5. coastal patrol—blockade
6.* underwater detection
7. underwater neutralization or kill
8.* defense against air targets
9. denial of facilities useful to enemy
10. destruction of distant surface targets
11.* reconnaissance in surface combat area
12.* amphibious operations
13. destruction of close surface target by air
14. destruction of close surface targets by surface action: anti-personnel
15. destruction of close surface targets by surface personnel: anti-armor
16.* mobile logistic support
17. strategic sealift
18. aid postwar recovery

Cold War Missions

19.* weakening existing political and military control
20.* border observation
21.* creation of land barrier
22. separation of hostile military units
23.* neutralization of surface forces without destruction
24.* control of land area
25. raids

*Final missions selected for Table A-2

TABLE A-1 (continued)

Possible Future Missions

26* defense of natural resources

27. destruction of natural resources

28. punitive

General War Missions

29. deterrent force patrols

30.* CONUS ASW defense

31. retaliatory destruction of population targets

32. postretaliation reconnaissance

33. postretaliation operations

34. aid postwar recovery

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*Final missions selected for Table A-2

TABLE A-2
CONSOLIDATED LIST OF SELECTED MISSIONS

Mission no.	Mission description	Important functions (activities) within mission
1	Strengthening will to resist	Delivery of supplies and personnel approach; air defense; submarine defense, launch and recover; strike aircraft; surface operations; submarine operations; air operations, amphibious operations and associated activities; detect and locate enemy personnel; neutralize or destroy resistance to advance; fire commands and communications, detect and locate enemy armor; defend against natural resources, detect threat; nullify and destroy source. Presumably encompasses all naval operations.
3	Long-range reconnaissance	Ship and shore based aircraft operations. Launch aircraft, mobile platform, locate targets, return to base.
6	Underwater detection	Long-range detection of submarines, coordination of ASW for interception, short range acquisition and classification.
8	Defense against air target	Detect, classify, coordinate own force; intercept with aircraft and missiles; kill targets.
11	Reconnaissance in surface combat area	Approach, observe, report, and record; process and evaluate—carrier aircraft, helicopters, light aircraft, forward observers.
12	Amphibious operations	Destroy enemy air, missile, ground installations; defend against air and sea attack, sub attack; prepare objective area, land forces, provide close air support and missile support, logistic support; command and control; use fast carrier forces, shore bombardment forces, airborne assault, landing craft.
16	Mobile logistic support	Transit rendezvous, transfer stores/fuel, retire; air defense, submarine defense.
19	Weakening existing political and military control	Transit, land, infiltrate, sabotage, subvert, communicate with support use of mobile platforms, ships, subs, covert amphibious landing, supply, guerilla and commando landing and operations.
20	Border observation	Detect and identify significant violations, long- and short-range reconnaissance, sensors.
21	Creation of land barrier	Obstruct or detect and destroy border violations and infiltrators; use mines, obstacles, patrols.
23	Neutralization of surface forces without destruction	Detect and report violation; intercept, command and control; attack and destroy enemy ships and subs; maintain mine fields reconnaissance—similar to 19 and 21, also.
24	Control of land area	See mission no. 1, interdict and isolate objective; conventional and nuclear weapons, aircraft, detections; fire command and control; neutralize artillery; self-propelled guns, small arms fire, long- and short-range reconnaissance; identify guerrillas; alarm trafrass; capture; CW BW warheads.
26	Defense of natural resources	Detect, threat, nullify, attack and destroy source; BW CW detectors; weather and climatological data, air strike, air defense, counter force.
30	CONUS ASW defense	Detect and classify subs at long range, coordinate ASW elements; short-range acquisition, destroy subs and sub-launched missiles, AIR BW systems bombs, torpedoes, subroc, mines, depth charges.

TABLE A-3
SENSITIVITY OF MISSIONS TO GEOPHYSICAL FACTORS

	Clouds			Thunderstorms			Hurricanes			Fog			EMP*		Surface stability		Underwater sound trans.						Ranking order of sensitivity	
Mission number	Dissipate	Generate	Prediction	Dissipate	Generate	Prediction	Dissipate	Generate	Prediction	Dissipate	Generate	Prediction	Control	Prediction	Control	Prediction	Control	Prediction	Magnetic anomaly	Storm surges	Earthquakes	Tsunamis	All factors	Only major† factors
1	–	C	P	C	C	P	C	C	P	–	C	–	–	–	–	–	–	–	–	–	–	–	2	1
3	C	–	P	–	–	P	C	–	P	C	–	P	–	P	–	–	–	–	–	–	–	–	3	2
6	–	–	–	–	–	–	–	–	–	–	–	–	–	P	C	P	C	P	P	–	–	–	6	–
8	–	C	P	–	–	P	–	–	P	–	C	P	C	–	–	–	–	–	–	–	–	–	4	3
11	C	–	P	C	–	P	–	–	–	C	–	P	–	P	–	–	–	–	–	–	–	–	4	3
12	–	–	P	–	C	P	–	C	P	–	C	P	–	P	C	P	C	P	–	P	–	–	1	2
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	C	P	–	–	–	–	8	–
19	–	–	–	–	C	–	–	C	P	–	C	–	–	–	–	–	–	–	–	–	–	–	6	4
20	C	–	P	–	–	P	C	–	–	C	–	P	–	P	–	–	–	–	P	–	–	–	3	3
21	–	–	–	–	C	–	–	C	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	6
23	–	–	–	–	C	–	–	C	–	–	C	–	–	–	–	–	–	–	–	–	–	–	7	5
24	–	–	–	–	C	–	–	–	–	–	–	–	–	P	–	–	–	–	P	–	–	–	7	7
26	C	C	P	C	–	P	C	–	P	–	–	–	–	–	–	–	C	P	–	P	–	–	2	2
30	C	–	–	–	–	–	–	C	P	–	–	–	–	–	–	–	C	P	P	–	–	–	5	5

*Electromagnetic Propagation (communications, radar, etc.)
†Factors with the greatest potential for future exploitation through improved prediction, modification, or control [1].

TABLE A-3
SENSITIVITY OF MISSIONS TO GEOPHYSICAL FACTORS

	Clouds			Thunderstorms			Hurricanes			Fog			EMP*		Surface stability		Underwater sound trans.						Ranking order of sensitivity	
Mission number	Dissipate	Generate	Prediction	Dissipate	Generate	Prediction	Dissipate	Generate	Prediction	Dissipate	Generate	Prediction	Control	Prediction	Control	Prediction	Control	Prediction	Magnetic anomaly	Storm surges	Earthquakes	Tsunamis	All factors	Only major† factors
1	–	C	P	C	C	P	C	C	P	–	C	–	–	–	–	–	–	–	–	–	–	–	2	1
3	C	–	P	–	–	P	C	–	P	C	–	P	–	P	–	–	–	–	–	–	–	–	3	2
6	–	–	–	–	–	–	–	–	–	–	–	–	–	P	C	P	C	P	P	–	–	–	6	–
8	–	C	P	–	–	P	–	–	P	–	C	P	C	–	–	–	–	–	–	–	–	–	4	3
11	C	–	P	C	–	P	–	–	–	C	–	P	–	P	–	–	–	–	–	–	–	–	4	3
12	–	–	P	–	C	P	–	C	P	–	C	P	–	P	C	P	C	P	–	P	–	–	1	2
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	C	P	–	–	–	–	8	–
19	–	–	–	–	C	–	–	C	P	–	C	–	–	–	–	–	–	–	–	–	–	–	6	4
20	C	–	P	–	–	P	C	–	–	C	–	P	–	P	–	–	–	–	P	–	–	–	3	3
21	–	–	–	–	C	–	–	C	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	6
23	–	–	–	–	C	–	–	C	–	–	C	–	–	–	–	–	–	–	–	–	–	–	7	5
24	–	–	–	–	C	–	–	–	–	–	–	–	–	P	–	–	–	–	P	–	–	–	7	7
26	C	C	P	C	–	P	C	–	P	–	–	–	–	–	–	–	C	P	–	P	–	–	2	2
30	C	–	–	–	–	–	–	C	P	–	–	–	–	–	–	–	C	P	P	–	–	–	5	5

*Electromagnetic Propagation (communications, radar, etc.)
†Factors with the greatest potential for future exploitation through improved prediction, modification, or control [1].

TABLE A-5
DETAILED INFORMATION FOR LIST OF CANDIDATE MISSIONS

Mission	Factor	Geophysical warfare concept	Relevant employment*	Affected functions in the mission
12 Amphibious landing	Clouds and precipitation	Produce extensive damaging precipitation	–	–
		Timing or planning operations thru prediction	E-P	Defend against air attack; Provide close air support; Supply logistic support
	Hurricanes	Produce extensive damaging wind and precipitation effects	E-C	Feasibility questionable
		Timing or planning operations thru prediction	E-P	All activities
	EMP condition	Timing or planning operations thru prediction	E-P	–
	Fog	Improve visibility thru dissipation	E-C	Feasibility questionable
		Timing or planning operations thru prediction	E-P	Destroy enemy installations; Approach objective area; Defend against air attack; Land forces; Provide close air support; Supply logistic support, air and surface; Coordinate operations
	Surface stability	Improve platform stability for sea-borne systems and operations by reducing wave amplitude	E-C	Destroy enemy installations; Defend against air attack(?); Land forces; Provide air support; Supply logistic support
		Timing or planning operations thru prediction	E-P	Ditto
	Underwater sound	Improve efficiency of undersea detection systems thru prediction	E-P	Defend against submarine attack

*E—mission enhancement; W—weapon; P—prediction; C—control (including modification): thus, E-P denotes mission enhancement through improved prediction of geophysical factors.

Table A-5 (continued)

Mission	Factor	Geophysical warfare concept	Relevant employ-ment*	Affected functions in the mission
1 Strengthen will to resist	Clouds and precipitation	Demonstrate capability to produce extensive damaging precipitation	W-C	Show of force
		Augment water supplies through beneficial precipitation	W-C	Defense of natural resources
		Prevent excessive damaging precipitation on friends	W-C	Defense of natural resources
	Hurricanes	Demonstrate capability to produce extensive damaging effects on enemy	W-C	Show of force
		Prevent excessive damaging effects on friends	W-C	Defense of natural resources
		Timing or planning operations thru prediction	W-P	Defense of natural resources
	Fog	Demonstrate ability to reduce damaging effects thru fog production and intensification of natural air pollution or interference with commerce and traffic	W-P W-C	Show of force
26 Defense of natural resources	Clouds and precipitation	Augment water supplies through beneficial precipitation	—	—
		Prevent excessive damaging precipitation on friends	—	—
		Timing or planning operations thru prediction	E-P	Evasion
	Hurricanes	Prevent excessive damaging effects on friends	E-C	Nullify source
		Timing or planning operations thru prediction	E-P	Evasion
	Storm surges	Minimize damaging effects at shorelines thru prediction	E-P	Evasion

Table A-5 (continued)

Mission	Factor	Geophysical warfare concept	Relevant employ-ment*	Affected functions in the mission
19 Weakening political & military control	Clouds and precipitation	Produce extensive damaging precipitation	W-C	Sabotage, subvert
	Hurricanes	Produce extensive damaging effects	W-C	Sabotage, subvert
		Timing or planning operations thru prediction	W-P	Infiltrate, communicate with support
	Fog	Produce damaging effects thru fog production and intensification of natural air pollution or interference with commerce and traffic	W-C	Sabotage, subvert
23 Neutralization of surface forces w/o destruction	Clouds and precipitation	Produce extensive damaging precipitation	—	—
	Hurricanes	Produce extensive damaging effects	W-C	Incapacitation, diversion, containment
24 Control of land area	Clouds and precipitation	Produce extensive damaging precipitation	E-P E-C	Hamper movement, harass
	EMP	Timing or planning operations thru prediction	E-P	Detect, locate, identify guerrillas
	Magnetic anomaly	Improved efficiency of magnetic anomaly detection systems	E-P	Detect, locate, identify guerrillas
21 Creation of land barrier	Clouds and precipitation	Produce extensive damaging precipitation	—	—
	Hurricanes	Produce extensive damaging effects	W-C W-P	Obstruct border violations
3 Long-range reconnaissance	Clouds and precipitation	Improve visual, optical and electronic visibility thru dissipation of clouds and precipitation	E-C	Locate targets
		Timing and planning operations thru prediction	E-P	Locate targets

Table A-5 (continued)

Mission	Factor	Geophysical warfare concept	Relevant employment*	...ted functions ... the mission
	Hurricanes	Improve visual, optical and electronic visibility thru suppression or alteration of course	—	
		Timing or planning operations thru prediction	E-P	
	EMP	Timing or planning operations thru prediction	E-P	Locate targets
	Fog	Improve visual and optical visibility thru dissipation	E-C	Locate targets
		Timing or planning operations thru prediction	E-P	
20 Border observation	Clouds and precipitation	Improve visual, optical and electronic visibility thru dissipation	E-C	Detect, identify, locate violations
		Timing or planning operations thru prediction	E-P	
	Hurricanes	Improve visual, optical and electronic visibility thru suppression or alteration of course	E-P	Detect, identify, locate violations
	EMP	Timing or planning operations thru prediction	E-P	
	Fog	Improve visual and optical visibility thru dissipation	E-C	Detect, identify, locate violations
		Timing or planning operations thru prediction	E-P	
	Nightglow	Improve night visibility	E-P E-C	Detect, identify, locate violations
	Magnetic anomaly	Improved efficiency of magnetic anomaly detection systems	E-P	Detect, identify, locate violations
8 Defense against air targets	Clouds and precipitation	Reduce (?) visual, optical and electronic visibility thru production of clouds and precipitation	—	
		Timing or planning operations thru prediction	W-P	Reduction ...emy effectiveness; detect, classify

Table A-5 (continued)

Mission	Factor	Geophysical warfare concept	Relevant employ-ment*	Affected functions in the mission
	Hurricanes	Reduce visual, optical and electronic visibility thru production or intensification. Disrupt enemy air navigation and coordination, ability to launch and land aircraft	—	—
		Timing or planning operations thru prediction	W-P W-C	All activities (friend and foe)
	EMP	Produce unfavorable propagation condition	W-P	Enemy effectiveness
	Fog	Reduce visual and optical visibility thru production or intensification (screening smoke?)	W-C	Enemy effectiveness
		Timing or planning operations thru prediction	W-P	Enemy effectiveness; Detect, classify
11 Reconnaissance in surface combat area	Clouds and precipitation	Improve visual, optical and electronic visibility thru dissipation	E-C	Observe
		Timing or planning operations thru prediction	E-P	Observe
	EMP	Timing or planning operations thru prediction	E-P	Report
	Fog	Improve visual and optical visibility thru dissipation	E-C	Observe
		Timing or planning operations thru prediction	E-P	Observe
30 CONUS ASW defense	Clouds and precipitation	Improve visual, optical and electronic visibility thru dissipation	E-C	Detect, locate submarines at sea
	Magnetic anomaly	Improved efficiency of magnetic anomaly detection system	E-P	Detect, locate submarines at sea
6 Underwater detection	EMP	Timing or planning thru prediction	E-P	Detect, classify, coordinate ASW elements
	Surface stability	Improve platform stability by reducing wave height	E-C	
		Time or planning thru prediction	E-P	
	Underwater sound transmission	Improve efficiency of undersea detection systems	E-P	Detect, locate submarines at sea
	Magnetic anomaly	Improved efficiency of magnetic anomaly detection systems	E-P	Detect, locate submarines at sea

TABLE A-6
CONSOLIDATED LIST OF CANDIDATE MISSIONS
(Those having major aspects in common are grouped together)

Mission function group	Major aspects	Mission number and description
A	Combined aspects of groups B and C	12 Amphibious operations
B	Destructive effects of phenomena	1 Strengthening will to resist 26 Defense of natural resources 19 Weakening existing political and military control 23 Neutralization of surface forces w/o destruction 27 Destruction of natural resources 24 Control of land area (part of) 21 Creation of land barrier
C	Reconnaissance and target acquisition (surface and air)	3 Long-range reconnaissance 20 Border observation 8 Defense against air targets (acquisition) 11 Reconnaissance in surface combat area 24 Control of land area (part of) 30 CONUS ASW defense (part of)
D	Underwater detection	30 CONUS ASW defense

TABLE A-7
CANDIDATE FACTORS FOR ANALYSIS IN REFERENCE TO MISSION FUNCTION GROUPS*

(a) Mission Function Group A or Mission 12

Geophysical factor	Functions	Mode†	Systems
Clouds and precipitation	Defense against air attack	P	Target acquisition
	Provide close air support		Target acquisition, fire control
	Supply logistic support		Transfer vehicles, helicopter lift
Hurricanes	All functions	P	
EMP condition	Destroy enemy installations Defend [illegible] Coordinate op[illegible]	P	
Fog	Destroy enemy installations Approach objective area Defend against air attack Land forces Provide close air support Supply logistic support, air and surface Coordinate operations	P	
Surface stability	Destroy enemy installations Defend against air attack (?) Land forces Provide air support Supply logistic support	C, P	Target acquisition, fire control Sea-borne platforms TV Target acquisition, fire control TV, helicopter lift
Underwater sound	Defend against submarine attack	P	Sonar detection

*See Table A-6.

†This column indicates the mode of exploitation of the geophysical factor; i.e., whether through prediction (P) or control (C).

(b) Mission Function Group B

Geophysical factor	Geophysical warfare concept	Mode	Missions
Clouds and precipitation	Demonstrate capability to produce extensive damaging precipitation on enemy	C	1, 19, 23, 27, 24, 21
	Augment water supplies through beneficial precipitation	C	1, 26
	Prevent excessive damaging precipitation on friends	C	1, 26
Hurricanes	Demonstrate capability to produce extensive damaging precipitation on enemy	C	1, 19, 23, 27, 21
	Prevent excessive damaging effects on friends	C	1, 26
	Planning operations thru prediction	P	1, 26, 19
Fog	Demonstrate ability to produce damaging effects thru fog production or intensification	C	1, 19, 23
Storm surges	Minimize damaging effects at shorelines	P	26
Earthquakes	Produce damaging effects in enemy country	C	27
Tsunami	Produce damaging effects at enemy shoreline	C	27

TABLE A-7 CONTINUED

(c) Mission Function Group C

Geophysical factor	Geophysical warfare concept	Mode	Missions
Clouds and precipitation	Improve visual, optical and electronic visibility thru dissipation	C	3, 20, 11, 30
	Timing and planning operations thru prediction		
Hurricanes	Improve visual, optical and electronic visibility thru suppression or alteration of course	C	20
	Timing or planning operations thru prediction	P	3, 8, 30
EMP	Timing or planning operations thru prediction	P	3, 20, 11, 24
	Produce unfavorable propagation conditions	C	8
Fog	Improve visual and optical visibility thru dissipation	C	3, 20, 11
	Timing or planning operations thru prediction	P	3, 20, 8, 11
	Reduce visual and optical visibility thru production or intensification (screening smoke)	C	8
Nightglow	Improve night visibility	C	20
Magnetic anomaly	Improved efficiency of magnetic anomaly detection systems	P	20, 24, 30

(d) Mission Function Group D

Geophysical factor	Functions	Mode
EMP	Detect, classify, coordinate ASW elements	P
Surface stability	? ?	C, P
Underwater sound transmission	Detect, locate submarines at sea	P
Magnetic anomaly	Detect, locate submarines at sea	P

APPENDIX B

ANALYSIS OF THE SURFACE

SHIP-TO-SHORE MOVEMENT

OF THE

AMPHIBIOUS OPERATION

APPENDIX B. ANALYSIS OF THE SURFACE SHIP-TO-SHORE MOVEMENT OF THE AMPHIBIOUS OPERATION

This analysis of the ship-to-shore transit operation parallels and complements the analysis of, and with, the STS-2 simulation model, but is independent of it (see Section 4.0). In this analysis, a schematic representation was derived for areas of command responsibility, decision points between specific craft activities, and the lines of dependency between decision alternatives and craft movement and control activities. This analysis was performed to confirm understanding of the ship-to-shore transit operation and to make explicit the points of interaction between operations and the environment. Further, this analysis was necessary for proper evaluation of the STS-2 simulation model, as applied to the assessment of geophysical impacts.

While this operational analysis is not exhaustive and is based on limited study, it proved adequate for technique assessment, and served to dramatize the very finely detailed analysis that would be necessary for a truly comprehensive study. The information supporting the analysis was gleaned from Navy and Marine documents*, interviews with representatives from other agencies and companies (notably Stanford Research Institute), and extensive, illuminating discussions with active-duty military personnel (see Appendix D).

Figure B-1 graphically presents the interaction of the decisions in the flow and the resultant operations. The diagram shows the actions which the craft may be involved in and, in between the blocks, indicates the action; the diamond shapes indicate, with reference numbers, the decision flow or alternate flow that must be employed to progress through the network. This figure is referred to here as the craft movement flow.

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*Dept. of the Army and the Navy, 1962: Doctrine for Amphibious Operations. Report NWP 22 (A), July

Dept. of the Navy, 1961: The Amphibious Task Force Plan. Report NWIP 22-1 (A), August. CONFIDENTIAL

—, 1960: Naval Gunfire Support in Amphibious Operations. Report NWIP 22-2, March. CONFIDENTIAL

—, 1963: Employment of Aviation in Amphibious Operations. Report NWIP 22-3 (A), February.

—, 1962: The Naval Beach Group. Report NWIP 22-5, July.

—, 1962: Ship-to-Shore Movement. Report NWIP 22-6 (A), February.

The organization Fig. B-1 is prescribed by an attempt to trace craft movement through a round trip from boat pool to ship side, unload, and return to boat pool. The physical areas which the craft transits are indicated in the margins of the figure. The separation of control for craft action into three areas, shipside, transit, and beach, is to acknowledge separate controlling operatives, but does not imply that there is no interaction among them; the control areas are indicated at the center of the figure.

To trace the flow in detail, an uncomplicated situation will first be described. In this example the state of the sea is such that it causes no special problems to craft maneuvering, the height of the surf does not present any problems to successful transit by landing craft, the craft being followed are components of a serial, and there are no restrictions to visibility. See Decision Flow 1. In this case a high priority requirement is generated and given to the appropriate TAC-LOG unit which decides that this is the highest priority of any of the present requirements, and thus gives it first consideration of whichever craft types are available. In this example any type of craft needed is assumed available at the boat pool.

The boat pool may be near the line of departure (LOD) or may be near the ship to which it is about to be assigned; in the figure, the boat pool overlaps the shaded stripe to suggest one either at the LOD or near the ship. There are no restrictions to visibility in this case; therefore, no special resources to facilitate movement from the boat pool to shipside are required, as per Decision Flow 2. The order is given for craft to move to the assigned ship.

In the craft movement flow the progress has been from boat pool clockwise to queue via the independent transit block. Independent transit indicates that the craft did not need navigational assistance.

As the craft arrives at shipside it enters a queue which may or may not (queue = 0) exist. This queue represents the number of craft awaiting assignment of a specific load point at the ship.

To get to the load station at the ship, consideration must be given to sea state, ship type, craft type, ship action, and cargo assignment. Decision Flow 3 shows this sequence.

The sea may be in such a state (nominal) as to have no particular effect on the craft-ship marriage maneuver or may be in a state (adverse) which has adverse effects on the craft-ship marriage maneuver. Ship action refers to whether the ship is at anchor or underway. Ship type indicates whether the craft will load alongside the ship or load in a well deck. Craft type is considered to indicate the degree of difficulty of the craft-ship marriage.

Cargo assignment indicates the degree of difficulty of putting this specific cargo into the given craft type.

In this example the sea state has not particular effect on the craft-ship marriage, so that in the craft movement flow the progress is continued to the block marriage maneuver. The decision flow now continues from sea-state nominal to the combined effects of cargo type, load station (i.e., well deck or along side), ship action, all of which influence the total time during which craft is being loaded and, in turn, the time spent in the queue for this load station as shown in Decision Flow 3a. With the sea state nominal, the decision flow is through the block indicating minimum difficulty to loading due to environmental factors. Progress in the craft movement flow is now at block load.

This example is considering the movement of a serial; therefore, the next decision flow is via serial assembly specified?—YES as in Decision Flow 4. This trace considers whether the assembly area is at the ship or elsewhere (e.g., LOD), whether there are stragglers involved in the serial, and, if so, what action the stragglers should take. With the craft movement flow at block serial assembly, the decision of how the transit from serial assembly point to the LOD or to shore will be affected by visibility is next to be considered; see Decision Flow 5. Since this example does not have a restriction to visibility, the serial moves to the LOD via the independent transit block of the craft movement flow, if the assembly was not at the LOD. Here, the serial enters a series of queues, any of which may be zero. Beach queues are considered in Decision Flow 6.

These queues are controlled by the facilities at the beach for unloading and by resources available in case of high surf, which requires extra work to keep the beach clear of sunken or damaged craft. The first queue in this series establishes a priority of the craft or serials at the LOD waiting to unload. After the priority queue the beach control unit must consider whether the craft will require assistance in beaching, whether it will require assistance unloading, and whether it will require a special beach slot.

As the flow proceeds through each of the decision blocks, if the craft require some special resource or facility, the following question must always be asked: Is the resource or facility available? If not available the craft enter the associated queue and, depending on priority, may enter all the queues successively. In the craft movement flow the craft is at block queue. When beach control has gone through the decision process, the craft are ready to begin transit from LOD to the beach via the independent transit block. The craft begin transit through the surf, and depending on surf height and craft type, the transit to the beach is followed through a probability distribution declaring the movement was done successfully—block success; with some damage or delay—block qualified success; or craft was sunk—block killed. These options are shown in Decision Flow 7. The surf height for this example is low; therefore, the probability of a successful transit is high. The craft movement flow is now at block unload.

Surf conditions are again considered at block unload of Flow 7 which reflects delays caused by unfavorable surf conditions. Surf is favorable to unloading, thus the flow continues through block undamaged of Flow 8a to block retraction. The decision flow goes to block assistance required for retraction?—NO; damage during retraction?—NO in Flow 8b. Thus, the craft will retract with no delay. The decision of restriction to visibility and the associated problems of transit with or without special navigational aides is assessed again in Flow 9. With no restriction to visibility, the craft movement flow can proceed from unload to retraction to independent transit, hence, to boat pool after a successful trip without undue delays. The craft are then ready to be recycled.

In another example, in which conditions are postulated as adverse, a more complex path for the decision flow is necessary. In this example consider the sea state to be somewhat adverse; the surf height is great enough to present some difficulty to craft transit shoreward of the LOD, and some difficulty to unloading (transfer) operations; and, there is a restriction to visibility. The cargo to be transported does not have a high priority; not all craft types are available, and this example considers a serial assigned to one large craft in the craft employment plan. The procedure follows.

The requirement for this serial is processed by the TAC-LOG unit and the Decision Flow 1 begins with a priority being assigned to the serial; this is not the highest priority, but the serial will be required at the beach within a given time limit. The craft types available at the boat pool do not include the most suitable craft for the transfer of this serial because adverse conditions have slowed most operations. However, there is sufficient urgency for this serial to be delivered ashore that a smaller craft with a higher sensitivity to the environment must be used. The Decision Flow 1 has proceeded from priority assignment to the next step, chocie of a craft to be used. The choice of craft may be the result of one or more cycles through a decision loop determining the availability of successively less preferable craft types. The control officer in this example dispatches two craft, smaller than the type called for in the craft employment plan for this serial, because of capacity limitations of the available craft.

The visibility decision flow is next considered in Flow 2. The trace through this flow is from block is there a restriction visibility? to YES. The navigational aids required are assessed along with the craft which are available.

Assume one of the craft has the navigational equipment necessary for transit in a low visibility environment. The dispatch order is given by the control officer. The craft movement flow begins at block boat pool and proceeds to block queue via the block controlled transit. The controlled transit block implies that the craft movement was conducted via boat lanes under surveillance of a control ship.

In Decision Flow 3 is shown the process for determining whether the state of sea is too adverse for craft-ship marriage with the ship type and ship action involved. For this example, consider that the serial will be loaded at the side of the ship with the ship at anchor. Alternatives to these situations might be to load in a well deck or to load alongside a ship which is maneuvering to create a lee to facilitate loading. The decision flow now has proceeded from block assess craft loading factors through blocks indicating ship action and the type ship that the serial is embarked on. Regard the craft-ship marriage as accomplished, with some delay (as compared with the nominal sea state). In exceptionally rough seas the marriage may not be accomplished, in which case the craft will become available to the control officer again. One of the craft now moves from block marriage maneuver of the craft movement flow to load. The second craft remains in the queue. In this example, let the craft which has the navigational aids be the first loaded. The decision flow for loading is reviewed in Flow 3a, again considering sea state and cargo-craft assignment. The cargo-craft assignment implies that some cargoes are more easily and quickly loaded onto some types of craft than on other types of craft; at the same time sea state may further reduce the ease of loading the cargo. Again, in comparison with the nominal sea state and with a more suitable choice of craft type, the loading time required is longer. A series of blocks that would specify combinations of ship type, craft type, and cargo type would afford a more representative range of values to describe the craft loading activity, but these factors have been condensed in Flow 3a. When the first craft finishes loading it must wait for the second craft to accomplish the craft-ship marriage and to complete loading.

The craft which is loaded moves to block serial assembly in the craft movement flow after Decision Flow 4 has been considered.

To demonstrate alternatives in the decision flow, let the priority assignment of this serial be updated and require now that the loaded portion of this serial proceed to the beach without waiting for the second craft to complete loading—either because requirements at the beach are more urgent, or because difficulty in loading the second craft will require waiting too long. The loaded craft proceeeds in the craft movement flow to the LOD via the block controlled transit, implying use of boat lanes and control ship surveillance, as prescribed by Decision Flow 5.

At the LOD the series of queues assess the need for resources and/or assistance in the decision blocks craft load priority, beaching assistance required?, unloading assistance required?, special beach slot required?, and beach slot available?. As in the first example, in any of the blocks in which the flow is directed through YES, the availability of the resource or assistance must be queried and, depending on the YES or NO result, the craft may enter the associated queue. Decision Flow 6 depicts this series of questions.

When the decision that the craft may proceed to the beach has been reached, the probability of successful transit through the surf is assessed in Flow 7. This example has a high surf and thus a lower probability of successful transit. This craft enters the decision flow of transit through the surf via block qualified success. On the craft movement flow the craft is in block beaching maneuver. As the craft is beaching,the surf causes it to broach (turn broadside to the beach), and unloading is not feasible until it beaches properly. In this example, the craft needs assistance now to get under her own power again but does not need repairs. The decision flow has now come through blocks qualified success,assistance required?—YES. The resources required to right this craft may or may not be available, and consequently there may be an associated queue for this assistance. The decision flow proceeds to block unload t_1 through the blocks repair required?—NO. At this point the craft is in block unloading of the craft movement flow. If damage to the craft had occurred,the block unload t_2 or t_3 would have been appropriate. In the block unload t_2 a different range of unload times (than in unload t_1) more accurately describes the unload activity with some hindrance due to malfunction of some part of the craft. In the blocks signifying unloading, extra unload time for operations at the transfer line would also be reflected, because of surf.

In parallel with the unload activity in the decision flow is block assess damage during unloading, which may lead through a loop with another probability distribution describing susceptibility to damage, and consequently through a queue associated with repair assistance, if assistance is required. This is shown in Flow 8a.

In this example, however, regard the craft as not having been damaged during unloading, so that the decision flow is through block undamaged to block assistance required for retraction in Flow 8b. Due to surf conditions, assistance is needed for retraction and another queue for assistance, resources, is encountered. When the assistance is available, the decision flow considers whether there has been damage during retraction and, if so, was the craft damaged to the extent it might be considered sunk or destroyed (killed)? The craft in this example will be regarded as not damaged; therefore, the decision flow is through block damage during retraction—NO. The progress through the craft movement flow is at block retraction. The decision flow continues to block is there a restriction to visibility? (Flow 9) and, if so, the loop involving the necessary navigational aids and the availability of such aids is again required. In the craft movement flow the craft moves to block assembly, where retracting boats will be guided out to the LOD and continue transit to a boat pool, remaining within a return boat lane and under surveillance of a control ship. Before recycling the craft, the decision flow questions whether the craft is immediately available or whether some time is spent changing crews, refueling, etc.

With the first of the two craft that started this example completely through the flow cycle, a third route through the chart can be described by following the craft which was last mentioned as being at the load station of the ship.

The progress in the craft movement flow is at block load. The Decision Flow 4 begins again at block serial assembly specified? and proceeds through block YES to is remaining portion (of serial) to assemble or transit individually?

In this case the craft will transit individually with respect to craft assigned to this serial, but, with visibility considerations from Flow 5, the craft must find an alternative which will permit transit within boat lanes and guidance from a control ship. The progress through the visibility loop of the decision flow goes from block does assembled group have required navigational aids? through NO and the alternative is now to attach to a serial or a craft which has the necessary aids, or to request some capable craft to be dispatched expressly to guide this craft to the LOD. Through either of the alternatives the craft will be regarded as being at block serial assembly in the craft movement flow. The decision flow must go through the several questions regarding assistance or resources for unloading as described in Flow 6 for the first craft, then is ready to assess the probability of a successful transit or beaching maneuver in Flow 7. Because of the combination of geophysical events occurring at the same time, and the lack of navigational equipment aboard this craft, the probability of a successful transit through the surf is low, and for this craft the decision flow is through block killed.

As the craft is moving to shore it is sunk; the decision process must decide whether the cargo can be salvaged, for this case, YES. Some resources will be necessary to unload the sunken craft, thus a possible queue is created. The block unload t_4 provides a fourth set of unloading times which would be required to unload a craft under these circumstances. Another decision must determine whether the craft can be salvaged and, if so, what resources will be required, and whether they are available.

If the craft cannot be salvaged, a decision must be made whether it is necessary to clear the beach, as in Flow 8c, which will require use of another resource and a queue associated with this resource. For this example, consider that the craft is not salvageable but that beach clearance is required. The decision flow has progressed to block assess time to clear beach slot and the trace ends at block beach slot available after going through blocks queue and beach clearnace. The craft movement flow stops at block beach clearance.

These three examples demonstrate some of the possible impact points of geophysical factors on a simplified sketch of the surface portion of a ship-to-shore movement.

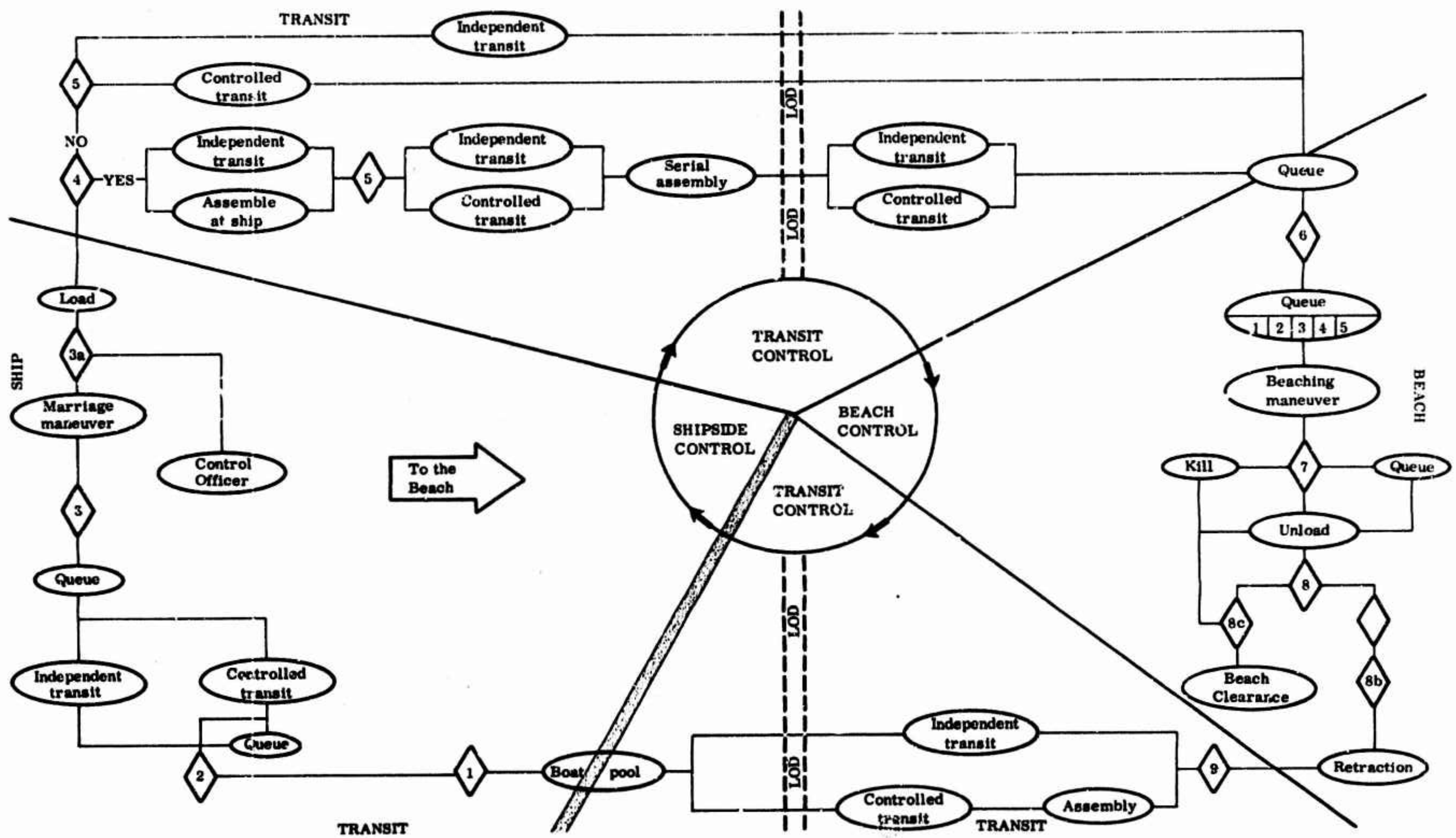
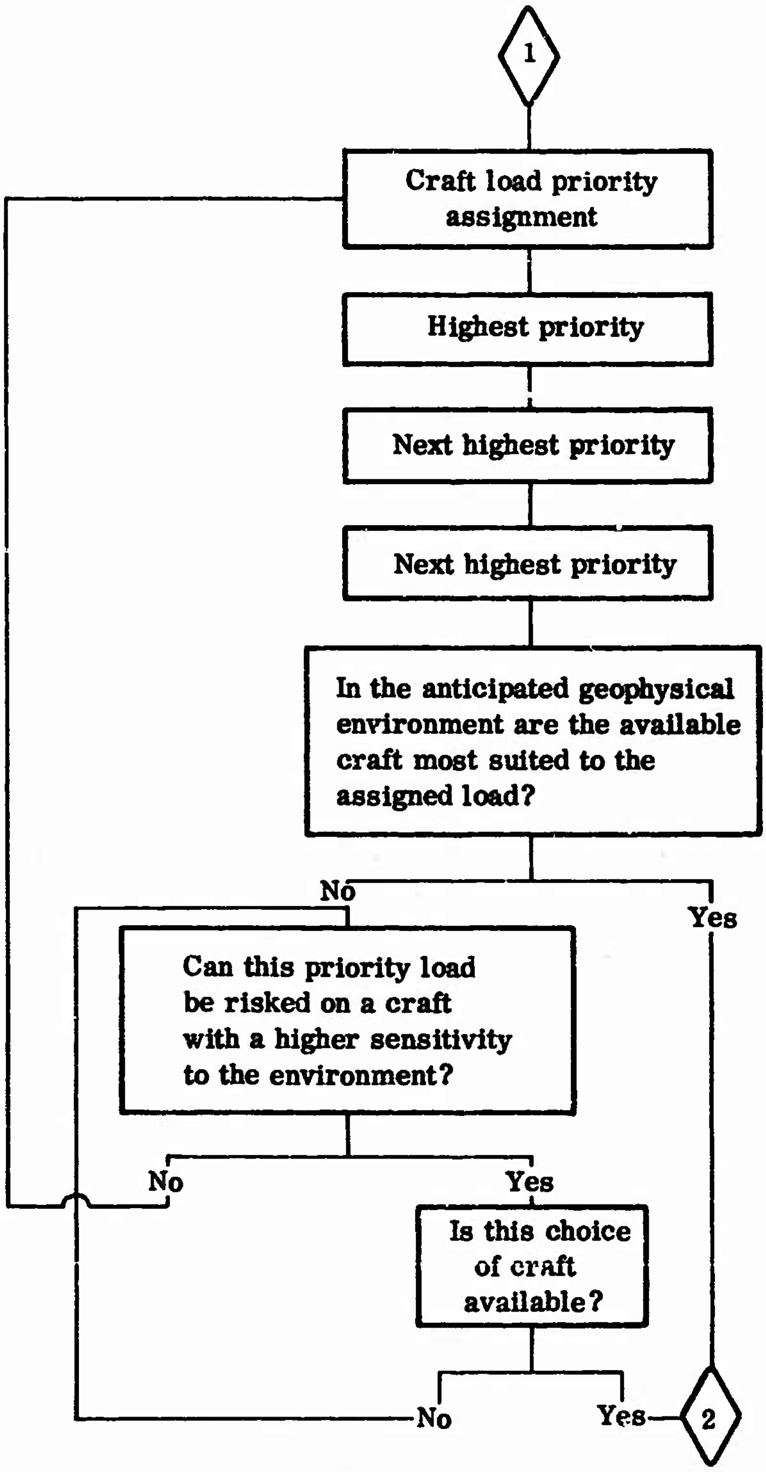
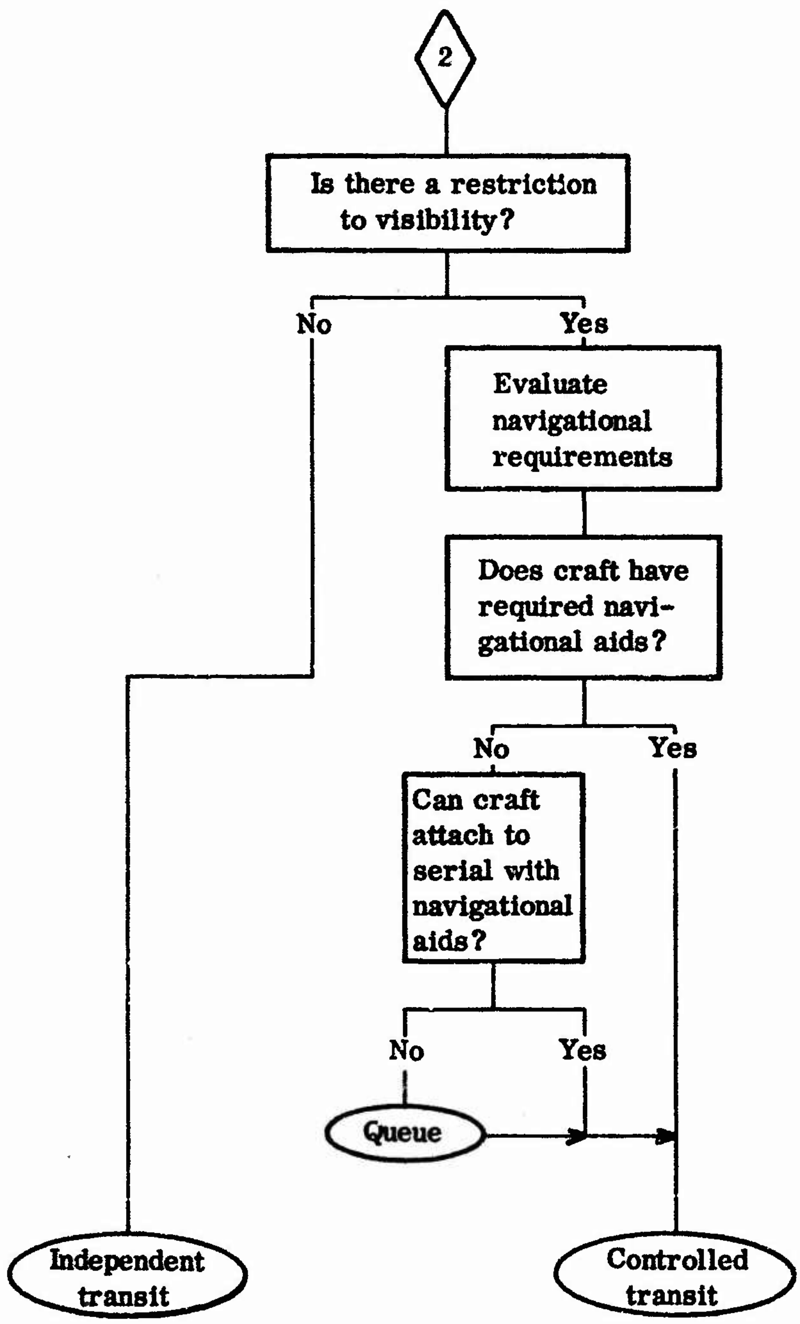


Fig. E-1. Craft Movement Flow

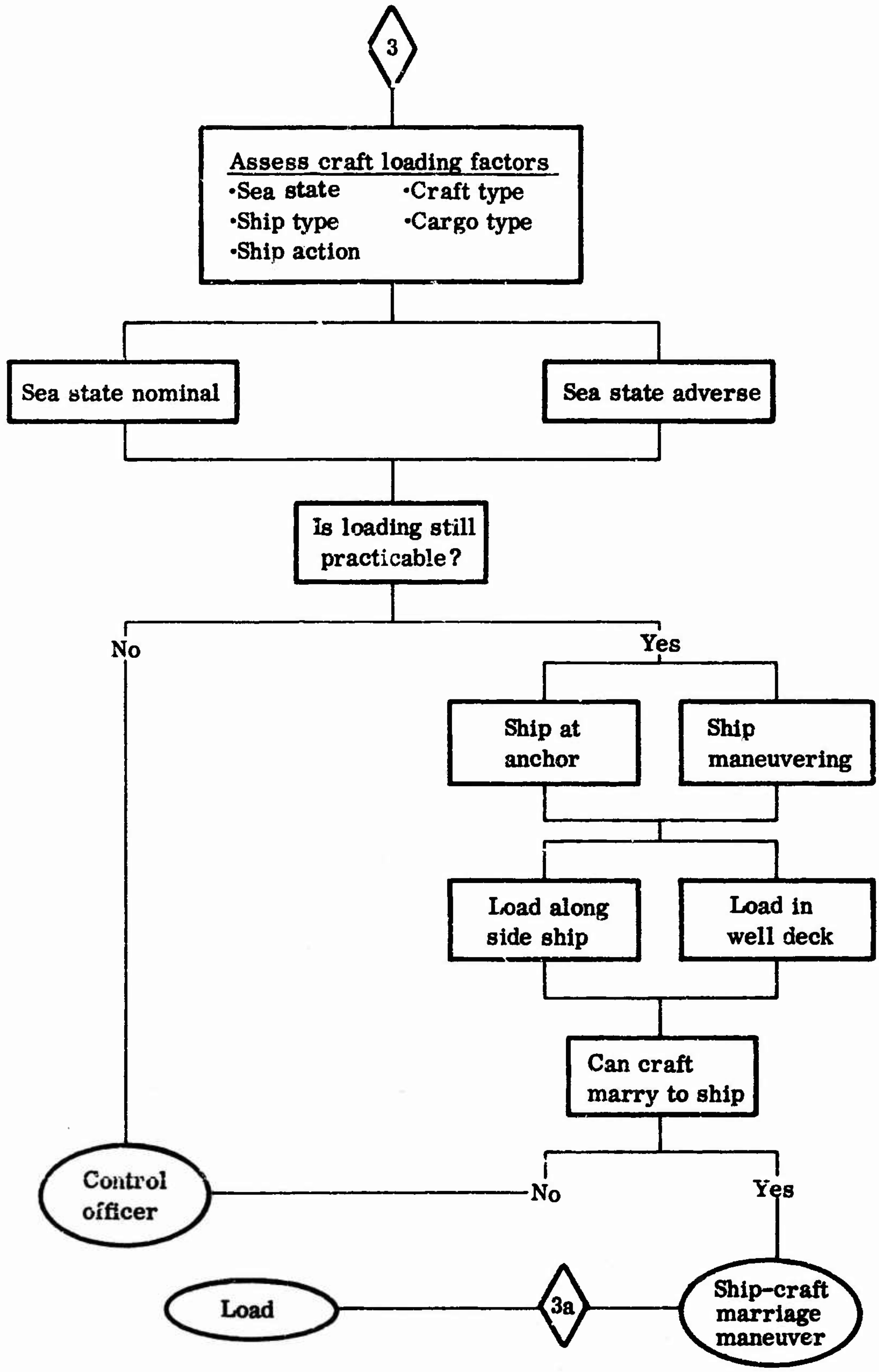
Flow 1. BOAT POOL DISPATCH TO SHIP



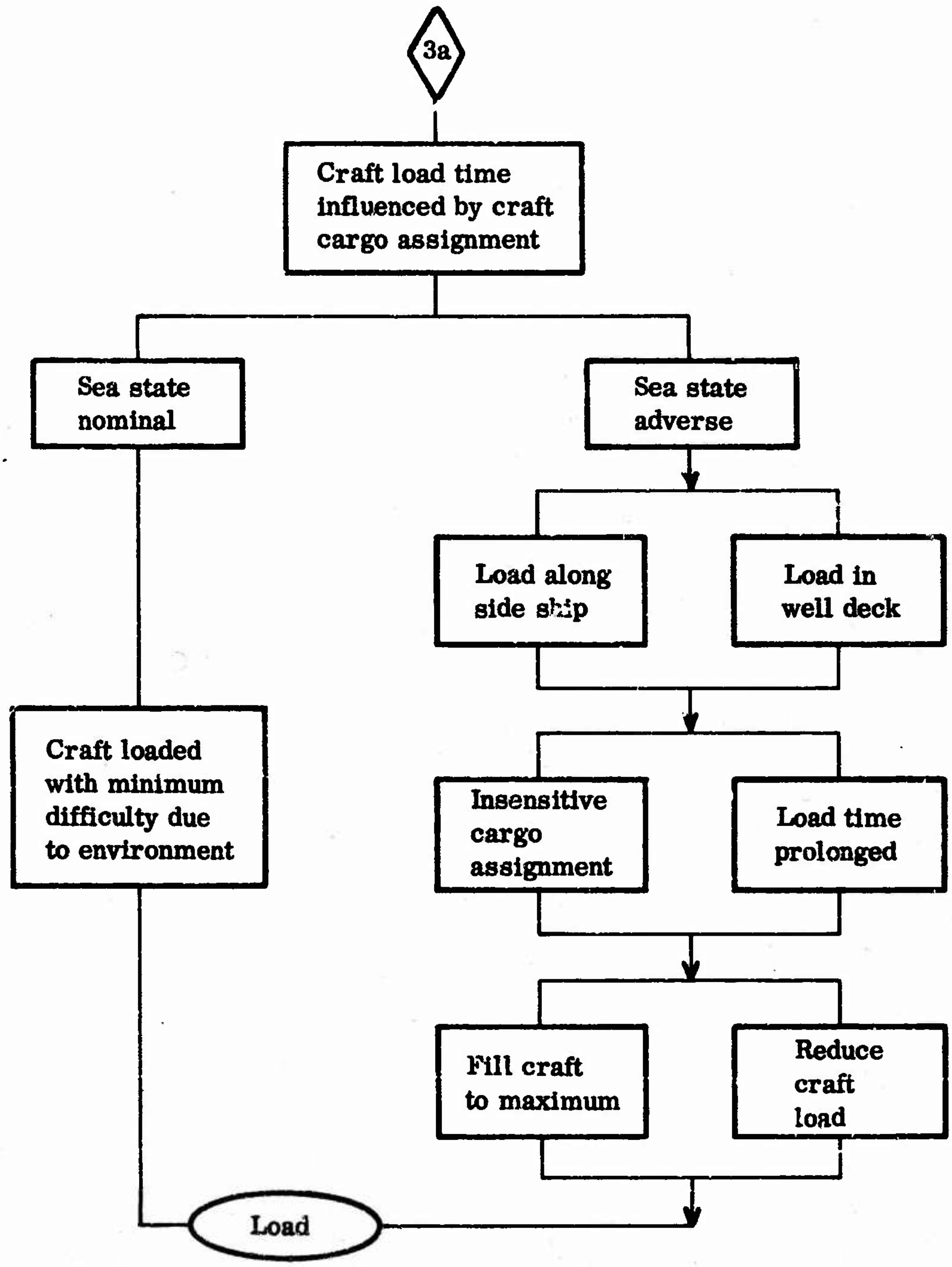
Flow 2. SHIPSIDE VISIBILITY RESTRICTIONS



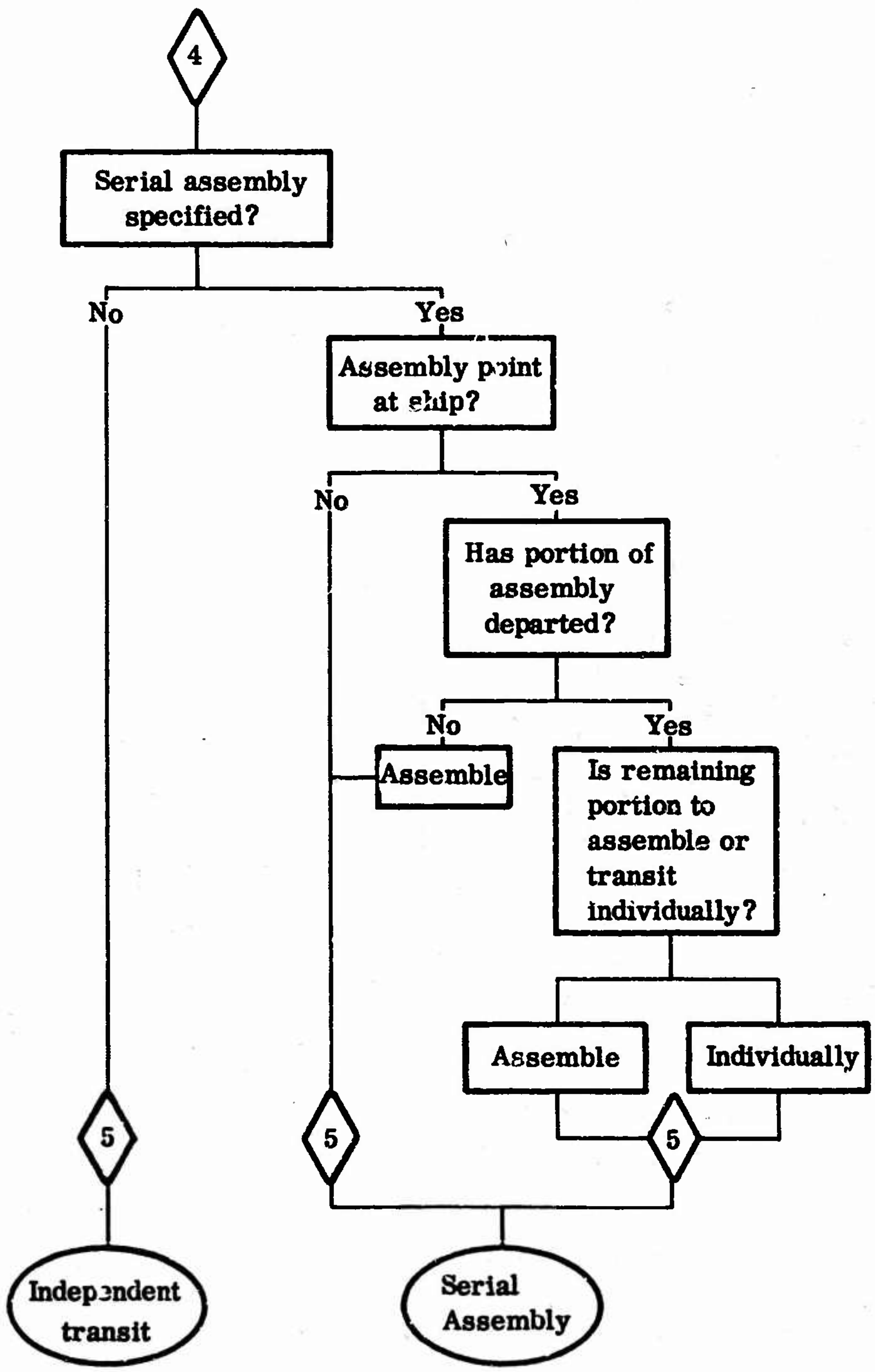
Flow 3. SHIPSIDE LOADING CONDITIONS



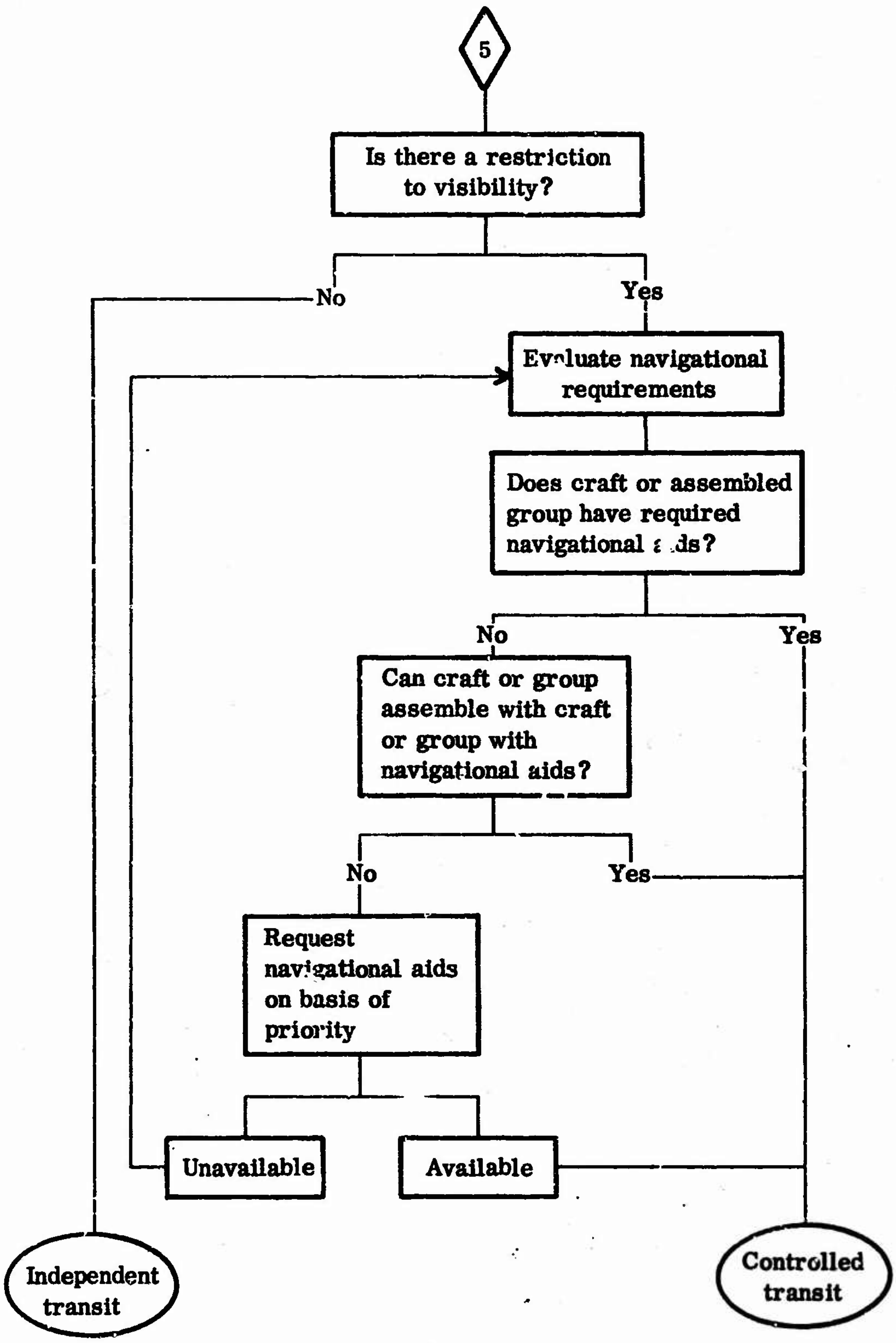
Flow 3a. SHIPSIDE LOAD TIME



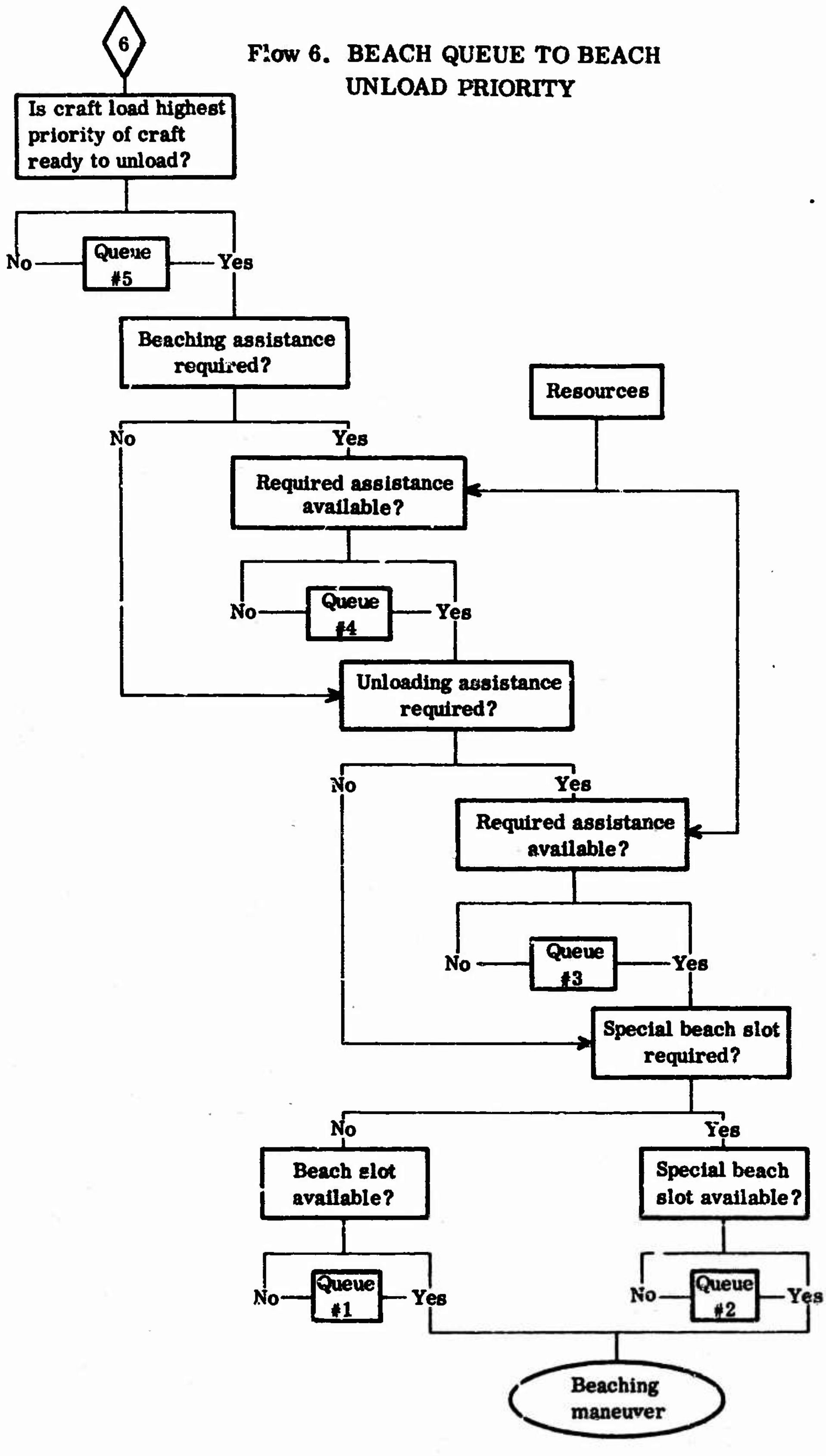
Flow 4. SHIPSIDE DISPATCH TO BEACH QUEUE

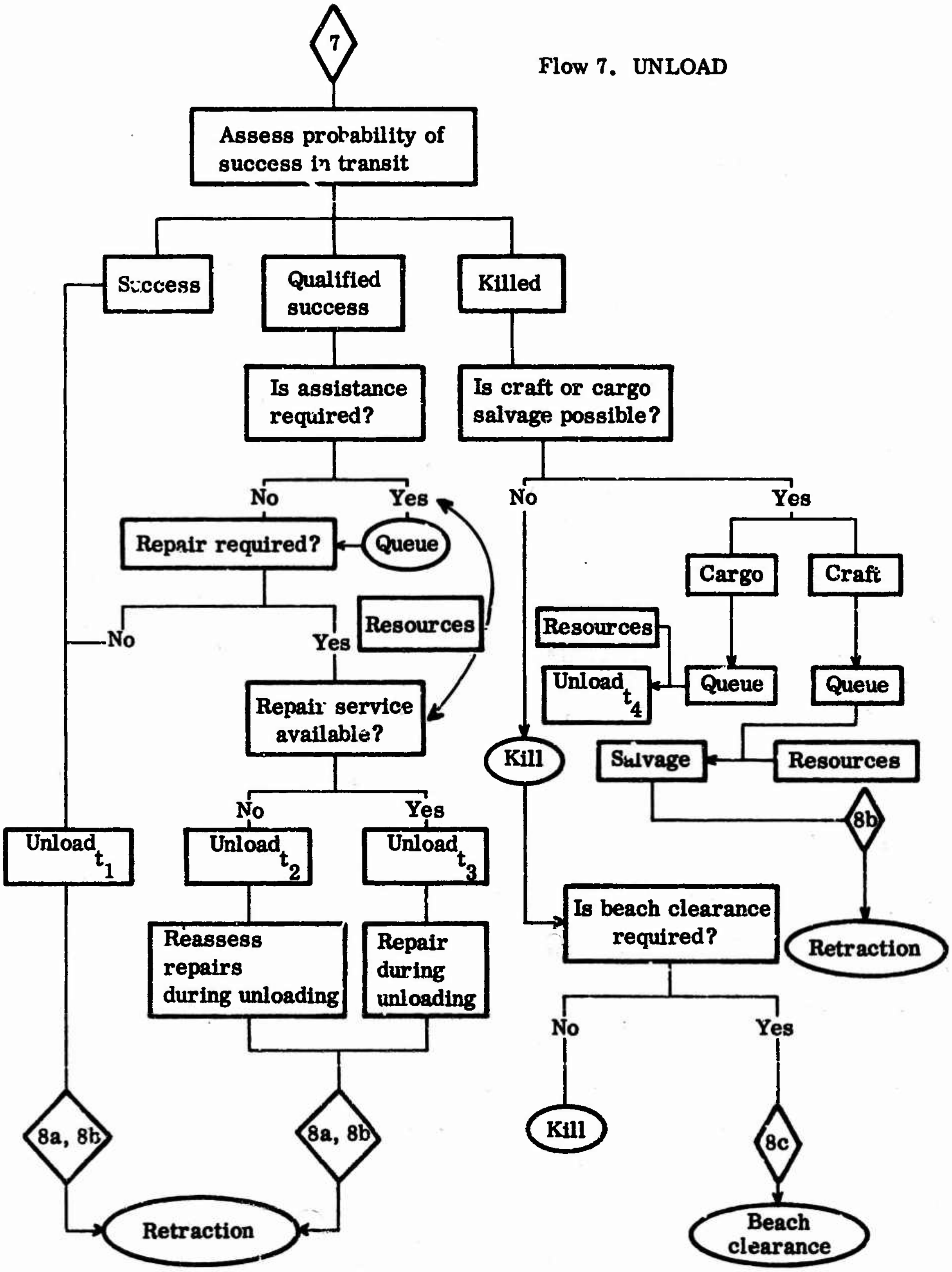


Flow 5. VISIBILITY RESTRICTION TO BEACH

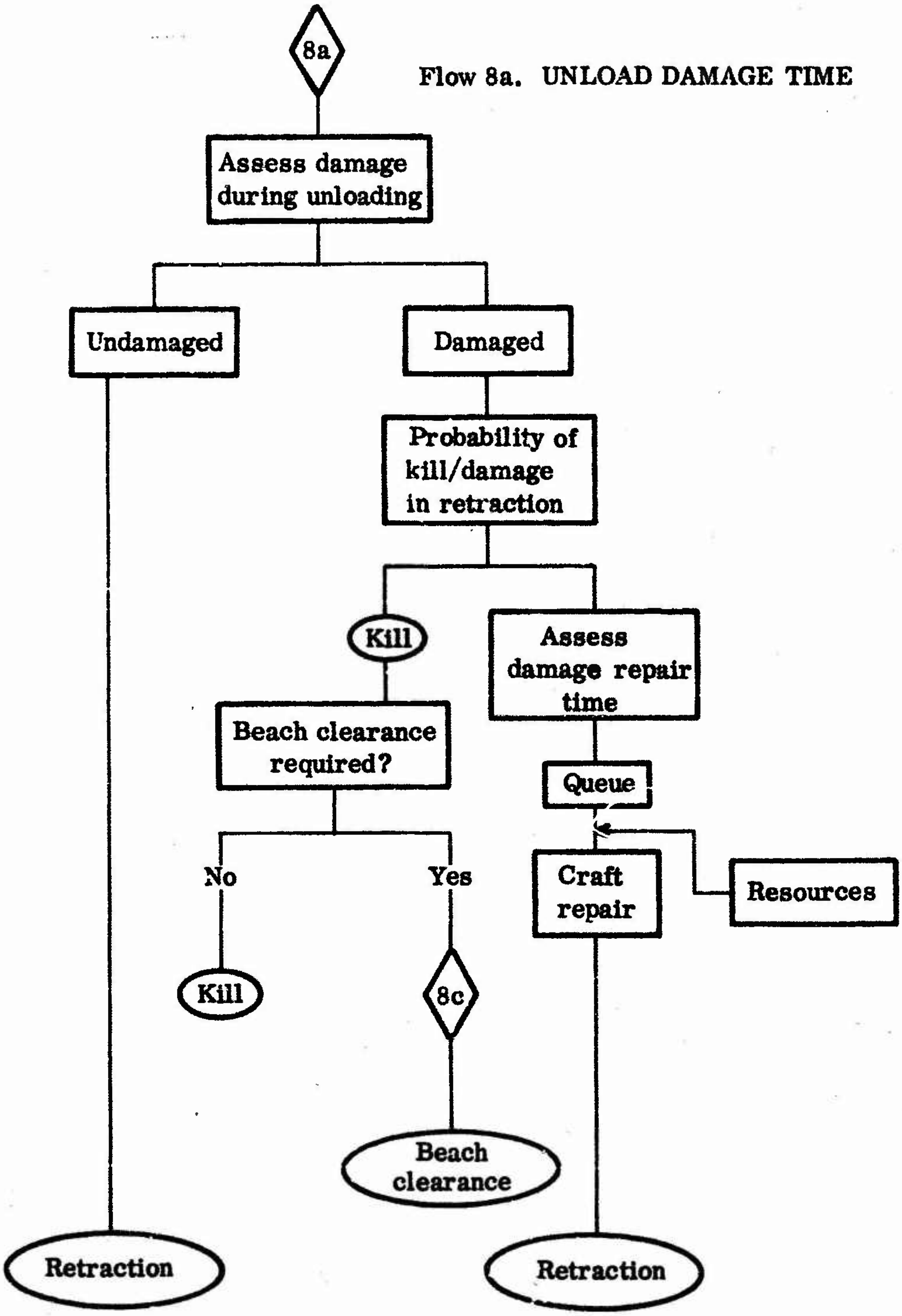


Flow 6. BEACH QUEUE TO BEACH UNLOAD PRIORITY

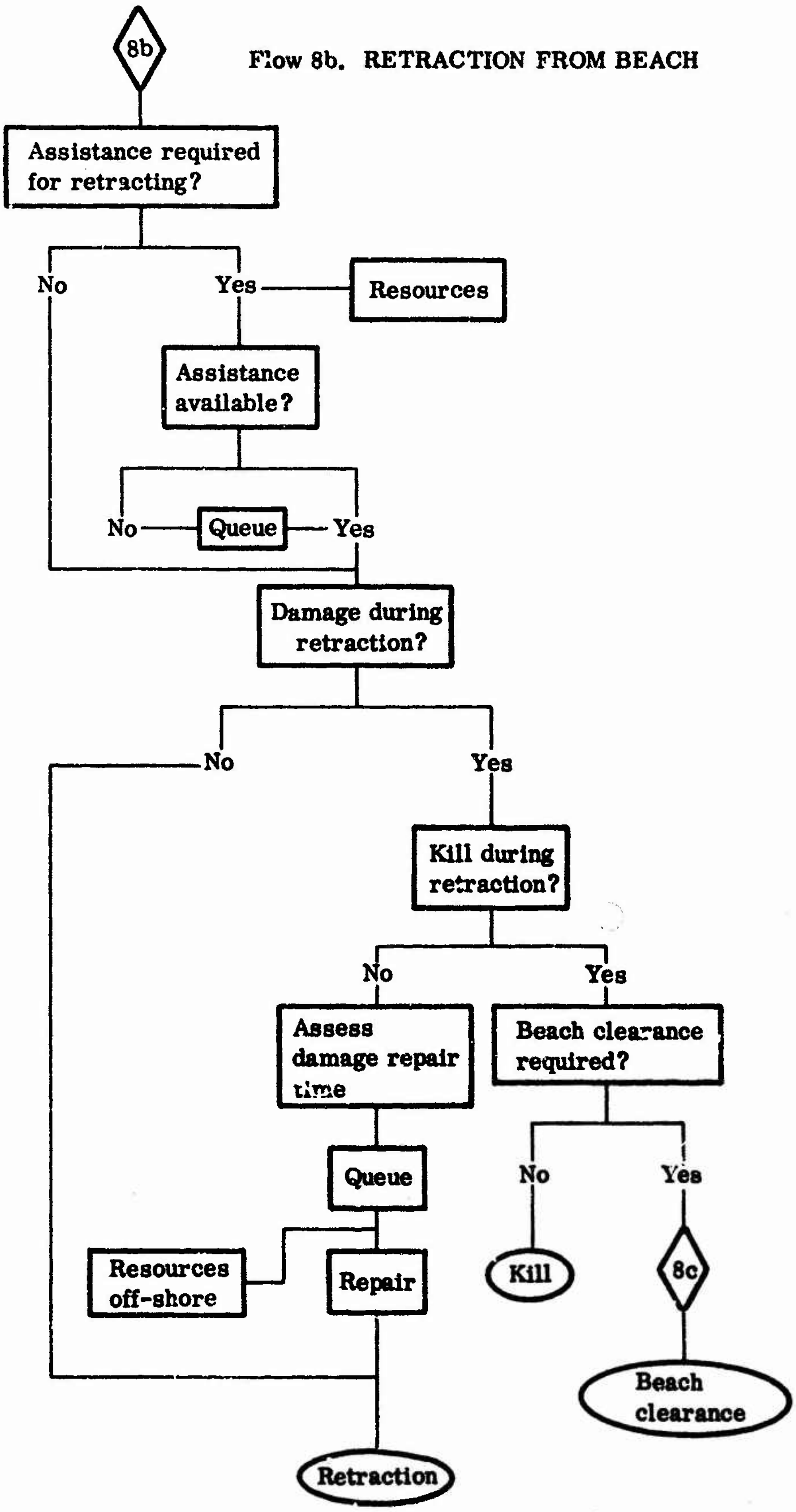



7
Flow 7. UNLOAD
Assess probability of success in transit
Success
Qualified success
Killed
Is assistance required?
Is craft or cargo salvage possible?
No
Yes
No
Yes
Repair required?
Queue
Resources
Cargo
Craft
No
Yes
Resources
Unload t_4
Queue
Queue
Repair service available?
Kill
Salvage
Resources
No
Yes
8b
Unload t_1
Unload t_2
Unload t_3
Is beach clearance required?
Retraction
Reassess repairs during unloading
Repair during unloading
No
Yes
Kill
8a, 8b
8a, 8b
8c
Retraction
Beach clearance

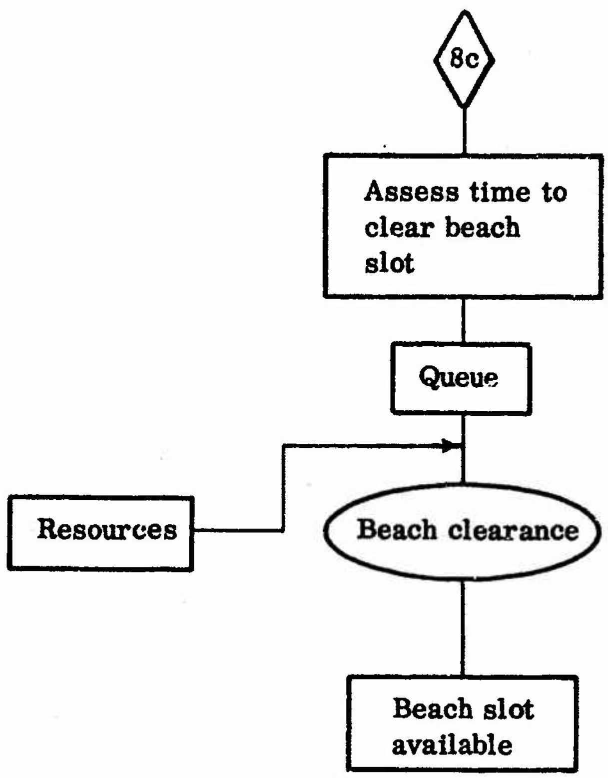
Flow 8a. UNLOAD DAMAGE TIME



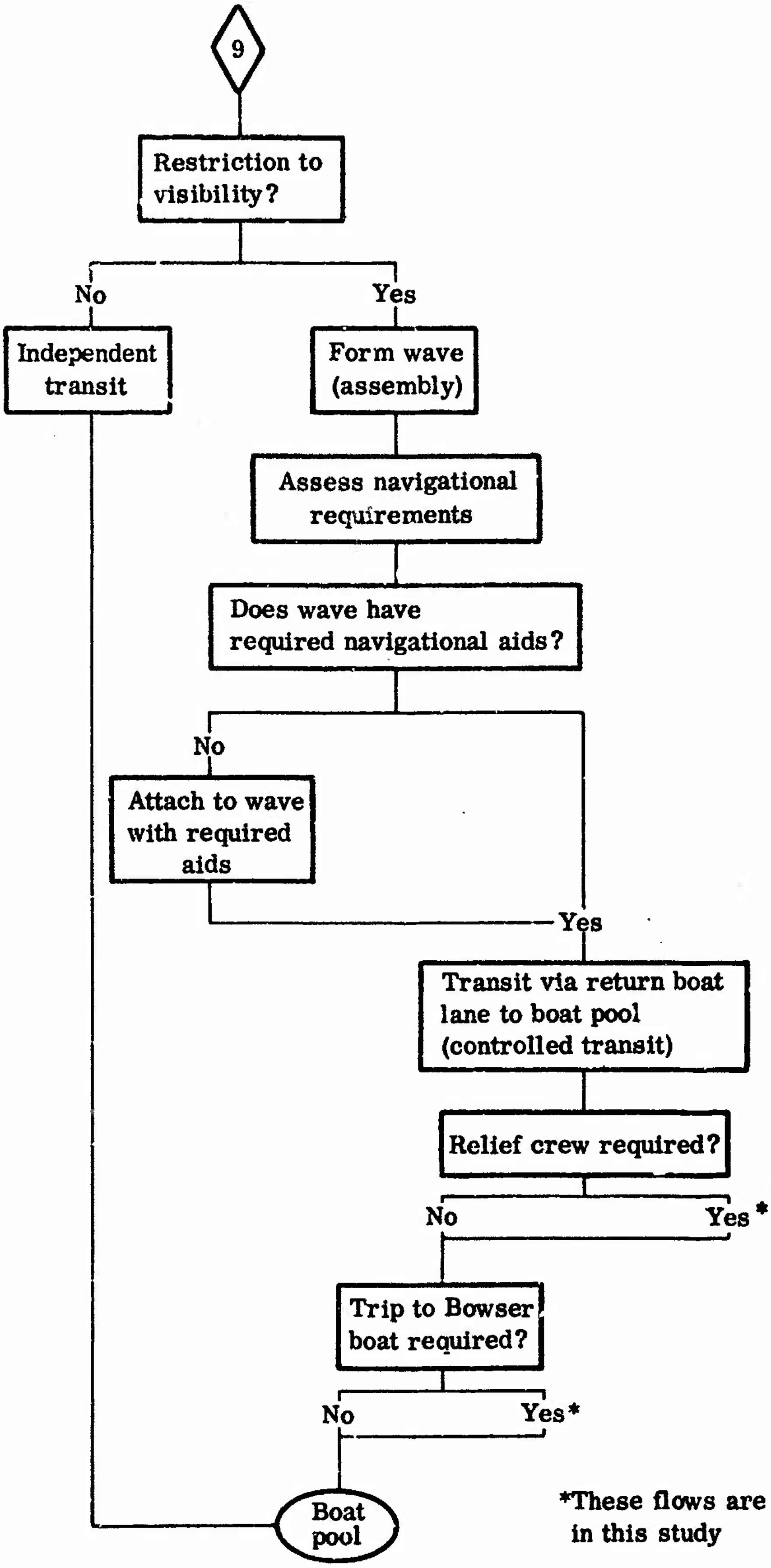
Flow 8b. RETRACTION FROM BEACH



Flow 8c. BEACH CLEARANCE



Flow 9. VISIBILITY - RETRACTION AT BEACH TO BOAT POOL



*These flows are not elaborated in this study

APPENDIX C

STS-2 SIMULATION MODEL

APPENDIX C. STS-2 Simulation Model

C.1 The Model

The ship-to-shore simulation model (STS-2)* selected for the sensitivity analysis was developed by the Naval Weapons Laboratory (NWL) primarily for the purpose of evaluating contingency war plans. As a consequence of this primary function the model was not specifically designed to provide the flexibility necessary for evaluating the effects of geophysical phenomena, except where this capability would enhance its basic function. In spite of this implied limitation, however, the model provides a framework for the voluminous bookkeeping functions necessary in any simulation, whatever its ultimate use, and has some degree of capability for environmental manipulation. This appendix describes the work done with the STS-2 model under this contract.

A substantial effort was made to determine: (1) the model's operating characteristics, as it responds to adjustments in the available simulation (input) parameters, and (2) the means by which geophysical influences could be incorporated in the model input parameters to obtain quantitative data on the overall response of the operation.

C.2 Operation of the Model

The model is manipulated by changing the input to tables that are used as reference by the program. It is necessary to describe the size of the operation (e.g., number of beaches, beach slots; number and types of ships; number and types of landing craft; characteristics of each type of craft; attrition rates; logistic requirements, etc.) for each run as input (see Section 4.3.4). The useful flexibility of this model, when thought of in terms of evaluating the sensitivity of amphibious operations to the environment,

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*STS-2 is a modified version of NWL's Ship-to-shore Model (STS). See:

Comer, C. P., and O. F. Braxton, 1964: The Ship-to-shore Model, NWL Report No. 1904. U.S. Naval Weapons Laboratory, Dahlgren, Virginia

Braxton, O. F., 1964: The Ship-to-shore Model (STS-2) User's Guide, Tech. Memo. K-26/64, U.S. Naval Weapons Laboratory, Dahlgren, Virginia.

Braxton, O. F., and D. R. Finley, 1964: Control Events for Increased Flexibility of the Ship-to-shore Model (STS-2), Tech. Memo. K-31/64, U.S. Naval Weapons Laboratory, Dahlgren, Virginia.

Comer, C. P., 1963: An Investigation of Factors Affecting Build-up Ashore in an Amphibious Landing (U), NWL Report No. 1860. U.S. Naval Weapons Laboratory, Dahlgren, Virginia. CONFIDENTIAL is diminished by the fact that inputs are variable within a single run only on a preset schedule.

Once the problem is defined to the program, as input in specific terms, the program generates logistic requirements and assigns craft to fulfill these requirements. The serial requirements compete with the logistic requirements for craft assignments, but scheduled serials do not compete with on-call serials for craft assignment (craft are assigned to these serials by the input). Once the craft is assigned to a ship for loading, the time until that craft is again available for assignment is determined by a straightforward system, which consists of a series of calculations concerning transit time from boat pool to ship, craft load time, transit time to LOD, transit time from LOD to beach, and craft unload time. Alternate routes may direct the craft through a queue at ship-side, or a queue at the beach when ready to unload; also, attrition may occur. If attrition occurs at the beach the craft is either "killed," and out of the game, or is damaged, in which case repair time is added to delay the time until the craft is again available.

C.3 Possibilities for Environmental Manipulation

A first order of consideration was to determine a satisfactory index for reflecting the impact on the operation of a change in the environment. The computer printout, reflecting the continuing progress of the operation, represents a large amount of complex information, and no simple index of the environmental impact was evident. From among the alternatives it was decided that the output measures most indicative of important environmental effects were the lengths of time necessary for the completion of selected significant portions of the operation; in particular, these were the times required for projecting ashore the scheduled, on-call, and non-scheduled serials, together with their necessary logistic support.

Analysis of the STS-2 simulation model, as compared to the analysis of the surface ship-to-shore phase of the amphibious operation (Appendix B), showed that the model did not possess the complexity needed for environmental manipulation; this was not unexpected, since that degree of complexity was presumably not required for its basic purpose, the evaluation of contingency war plans. This fact, however, did force the combining of multiple environmental effects into single simulation parameters (see Section 4.3). To do this, weighted averages were used, with their attendant potential for: (1) errors in the averages caused by difficulties of determining proper weighting functions, and (2) adverse effects on the capability of the simulation model to reflect the operation's sensitivity, because of the smoothing implicit in the averaging process.

The three events through which geophysical factors were brought to bear on the surface portion of the STS-2 simulation model are discussed in the following paragraph: (1) Load time is the average time required to transfer a unit of men, vehicles, or logistics from the ship to the landing craft. If the relation between sea state and load time can be determined, the load time inputs to the program will imply the environmental influences (see Section 4.2.1). (2) If the times for unloading craft by beaching, or by transfer of cargo to amphibian vehicles, can be averaged into one meaningful figure, unload time can be used to reflect environmental conditions. (3) Attrition probabilities can directly describe the likelihood of damage that high seas or rough surf can cause to the landing craft (see Section 4.2.2). Associated with the attrition probabilities, and as an extension of the surf damage concept, the range of time for repairs to attrited craft provides a further possibility for reflecting environmental influences in the simulation. The attrition probabilities also prescribe the number of craft disabled at the beach. Time to clear craft disabled at the beach is also an input variable to STS-2. Therefore, the range of times required to clear craft disabled at the beach might provide an indirect modification to the simulation results to reflect the effects of the environment. The opportunity to play attrition probabilities to reflect realistically the adverse environmental conditions occurs only once per trip, shoreward of the LOD, because all other attrition probabilities contained in the model can only reflect (for the purposes of this study) an adverse environmental condition (high sea state) that would be far beyond that expected in a real operation, even in extreme conditions.

Other possibilities for environmental manipulation, which were considered but not employed, are treated in the remainder of this section. The time to prepare an LST to unload at a beach or causeway is an input variable for the STS-2 model, and sea state has a significant bearing on the causeway marriage activity; the effects of varying sea conditions might be imposed here. However, this possibility was not pursued (see Section 3.2).

Craft characteristics input to the program, and thus potentially useable to reflect the environment, include speed, capacity (in short tons), and square ratio (which describes the useable square footage of a craft) of each craft type. The effects of reduced visibility on craft transit time could be partially fed into the program by changing the speeds at which craft travel. If the distance a craft must travel from ship to shore and return is changed by low visibility (requiring transit via boat lanes), this fact can be accommodated in the geographic location table of STS-2. Such a change of ship location, while it may be useful, was not employed, since it would have the craft travel equal distances both to the shore and back to the ship, instead of travelling a longer return route to the ship via a boat lane, as would be the real case.

The beach status table is another indirect means of reflecting geophysical impact. Changing the number of beach slots could indicate that some of the total slots are continually out of the game because they are being occupied by repair or salvage operations; but to accommodate this, the number of available beach slots would have to be determined dynamically during a run. Since it is undesirable to input a single value which is either more or less than the "correct" number of beach slots for the model to use during the entire simulation run, this was not done.

As was discussed previously, the model's limitations for environmental study are substantial, and their remedy would require extensive effort. NWL personnel were very cooperative in making adjustments to the model (as many as were feasible), but substantial difficulties remained. It should be pointed out that the necessary model modification work could be carried to a successful conclusion, but that the resources to undertake this task were not available under the present contract.

The remaining difficulties with the model in general relate to the fact that the real operation becomes even more complex as the environment becomes more adverse, while the model is unable to reflect this increasing complexity directly.

C.4 Preliminary Runs

To obtain the necessary data for an evaluation of the model's basic operating characteristics, the Naval Weapons Laboratory produced a number of runs in which the model parameters were exercised individually over a wide range of values. Table C-1 lists the variations in inputs prescribed by us and used in this first set of runs intended to thus exercise the parameters (and the model); since study of the environmental-operational parameter relationships had not, at that time, reached the point where realistic estimates were available, these inputs are artificial—and are not intended to imply real relationships between the environment and the operational parameters.

Analysis of these runs identified several difficulties that would require correction as the project progressed. Among these were difficulties associated with the operational framework and the forces involved: (1) the preliminary runs reflected only a part of the surface portion of the Regimental Landing Team (RLT) ship-to-shore movement, and thus was insufficient in operational scope for our purposes; and (2) the timing of the operation was atypical in that an unusually long time was allowed to elapse before the start of general unloading.

As a result of our receipt and analysis of these runs, NWL personnel made substantial adjustments to the basic input information as it reflects the content of the operations order being used and thus eliminated the problem of scope. The problem of timing is discussed below.

The preliminary runs also showed that the attempt to use one "representative" set of unloading times for all beaching craft (including LSTs), to reflect response to varying surf conditions, gave misleading results because of the gross distortion to unloading times caused by the inclusion of the LSTs. The parameters defining the craft ship-side loading times have a comparable weakness (aggregation) to that for unloading, with the exception that LSTs are not involved so that the distortion is less. These findings led us, in our subsequent production and diagnostic runs and analyses, to concentrate our attention, both in the inputs and the outputs, on the portion of the surface ship-to-shore movement not involved with the LSTs.

The pace of the requirements for vehicles, men, and logistics was not particularly demanding upon the simulated available facilities, nor was it considered realistic in the opinion of Navy personnel with amphibious experience (Appendix D). As a result, and after further consultation with NWL, additional preliminary runs were made in

TABLE C-1
INPUT DATA, PRELIMINARY RUNS

Run number	Sea state*	Surf height, ft†	Load time, min			Unload time, min			Attrition probabilities									
									Damaged at beach					Destroyed at beach				
			100 men	1 vehicle	1 lift logistics	100 men	10 vehicles	10 lift logistics	LVT	LCVP	LCM-6	LCM-8	LCU	LVT	LCVP	LCM-6	LCM-8	LCU
111	—	b	11	2	1	8	16	21	0	0	0	0	0	0	0	0	0	0
112	—	b	23	4	2	8	16	21	0	0	0	0	0	0	0	0	0	0
113	—	b	46	8	4	8	16	21	0	0	0	0	0	0	0	0	0	0
114	—	b	69	12	6	8	16	21	0	0	0	0	0	0	0	0	0	0
115	—	b	92	16	8	8	16	21	0	0	0	0	0	0	0	0	0	0
121	—	b	23	4	2	4	8	11	0	0	0	0	0	0	0	0	0	0
122	—	b	23	4	2	8	32	42	0	0	0	0	0	0	0	0	0	0
123	—		23	4	2	16	48	63	0	0	0	0	0	0	0	0	0	0
131	—	5	23	4	2	8	16	21	0	.07	.02	.005	0	0	.10	.05	.05	0
132	—	5	23	4	2	8	16	21	0	.07	.02	.005	0	0	.10	.05	.05	0
133	—	5	23	4	2	8	16	21	0	.07	.02	.005	0	0	.10	.05	.05	0
134	—	8	23	4	2	8	16	21	0	.17	.07	.05	.005	0	.30	.10	.05	.05
135	—	8	23	4	2	8	16	21	0	.17	.07	.05	.005	0	.30	.10	.05	.05
136	—	8	23	4	2	8	16	21	0	.17	.07	.05	.005	0	.30	.10	.05	.05
137	—	10	23	4	2	8	16	21	.01	.50	.15	.15	.06	.05	.999	.50	.50	.10
138	—	10	23	4	2	8	16	21	.01	.50	.15	.15	.06	.05	.999	.50	.50	.10
139	—	10	23	4	2	8	16	21	.01	.50	.15	.15	.06	.05	.999	.50	.50	.10

*Undefined when these runs were made.
†b = benign

NOTE: Repair times for all runs in this table were: maximum, 180 minutes; minimum, 60 minutes. Delay time to clear craft destroyed at beach in all runs: maximum, 30 minutes; minimum, 10 minutes.

which the time period from H-hour to the "time to start general unloading" was progressively reduced from its original time of 52 hours to more realistic times down to eight hours. This time squeeze was imposed so as to depict a more realistic situation in which delays due to increased loading times and higher attrition rates would demonstrate when and if the operation became sensitive to these changes. At the same time, NWL suggested and carried out experimental runs to study another problem, that of defining the "best" maximum number of craft to be permitted to accumulate in a ship-side queue. The number of craft allowed to queue at a ship's hold was increased from the original value of one, to values of four, five, and six, with a resulting reduction in the time required for the final, or non-scheduled, serials to be landed. The results of varying the number of craft in a queue at shipside are shown in Table C-2. By the time our study had reached the point of analyzing these runs, it had become necessary to analyze the computer output in great detail, to better understand the influences being investigated. In many instances the entire history of particular serials (cargo designations) were analyzed, even to the extent of tracing the complete sequence of activities of each individual craft involved in the transport of a serial. Inspection of Table C-2, which resulted from this type of detailed analysis, leads to the following types of conclusions: (1) The optimum "maximum craft queue" of those tested is four. This is seen from the table entries (serial landing times) of run numbers 700A, 601, 602, and 603, in which the craft queue maximum is one, four, six, and five, respectively; run 601, with a queue of four, gives the most consistent over-all reduction in landing times (previous NWL experience had indicated that the optimum would probably be in the 4—6 range, so the experiment was limited to these values). (2) To ascertain, among other things, why the landing time for serial 951 increased when the queue was increased from one to four (run 700A and run 601), run 610 was conducted holding prescribed logistics from starting ashore until H plus eight hours, in order to minimize competition between serials and logistics. As hoped, serial 951's time dropped to a minimum, showing that it was logistics competition which had interfered with serial 951 in run 601. To explore the potential of these runs for environmental manipulation, run 612 was conducted as a repeat of run 610, but with an adverse environment. The impact of the increased loading times, which reflect an adverse

TABLE C-2
SERIAL LANDING TIMES* AS A FUNCTION OF
MAXIMUM CRAFT QUEUE

	Maximum craft queue						
	1	4	6	5	4	4	—
Run No.	700A	601	602	603	610	612	612C†
Serial No.							
702	761	683	683	683	683	821	752
814A	1111	1023	1023	1023	1023	1393	1339
814B	2211	1939	1939	1939	1939	3075	2967
732	869	829	829	829	829	1025	936
840	2519	1441	1723	1625	1441	2069	1838
753	1045	890	890	890	890	1070	863
363	2125	1780	1768	1780	1780	2730	2498
601	1325	1166	1166	1166	1166	1558	1333
700	945	845	845	845	845	1030	1030
1	785	696	696	696	696	760	737
950	1639	1308	1448	1445	1308	2021	1554
951	1558	1593	1748	1616	1532	2340	1481

*The time that the serial landed, in minutes, where minute 360 is the time to start first assault wave.

†Run 612 calculated.

sea state, can be seen in the greatly extended serial landing times. In fact, it almost precisely reflects a simple arithmetic addition, as seen in the results headed "612 calculated." The table entries for this run are simply the products of the number of vehicles in each serial by the loading time per vehicle, and added to the time that serial started to load (an input parameter). Even without the addition of transit time, these numbers come close to the computer run values in the line next above, except for some of the serials in holds which also contain logistics (e.g., serials 950 and 951). Thus, except for serials located in holds where competition for loading would occur, the simulation aspect of the model is in essence a bookkeeping operation.

Once the time at which general unloading should begin and the maximum craft queue had been examined, the principal set of production runs was requested from NWL.

C.5 Production Runs

The production runs, numbered 700 through 711, consisted of progressive steps from a nominal to an adverse sea state, in four stages. The three runs in each sea state series represented, respectively, one case of benign surf height (one foot) and two cases of adverse surf height (five feet), the latter with inputs reflecting two different degrees of proficiency of the landing craft crews. Run number 710 was replicated a total of three times (710-0, 710-1, and 710-2) in order to examine the effect of attrition rate, which is governed by the generation of a random number*. The primary object of the production set of runs was to determine at what phase of the changing geophysical environment the operation began to be noticeably affected. Table C-3 shows the values of the input parameters used in these runs. The source of these data is discussed in Section 4.0 and in Appendix D. In these runs the increasingly adverse sea state is reflected in increased ship-side craft-loading times, and the effective surf height is reflected both in the craft attrition probabilities at the beach and in the craft repair times. The principle output of these runs is presented in the form of the time to land important serials, in Table C-5; these findings are treated (Section C.6) after the discussion of some diagnostic runs which became necessary.

Detailed analysis of the production runs revealed an unexpected and non-specified

*No change occurred because of the way the model plays the unloading and replacement of attrited craft (see Section C.6).

TABLE C-3
INPUT DATA, PRODUCTION RUNS

Run number	Sea state*	Surf height, ft†	Load time, min			Repair Time, min		Attrition probabilities													
								Damaged at beach							Destroyed at beach						
			100 men	1 vehicle	1 lift logistics	minimum	maximum	LVT	DUKW	LCVP	LCM-3	LCM-6	LCM-8	LCU	LVT	DUKW	LCVP	LCM-3	LCM-6	LCM-8	LCU
700	31/2	1_c	31	12	4	9	10	0	0	.05	.10	.10	0	0	0	0	0	0	0	0	0
701	31/2	5_c	31	12	4	18	35	0	0	.70	.55	.55	0	0	0	0	.80	.05	.05	0	0
702	31/2	5_o	31	12	4	12	19	0	0	.50	.10	.10	0	0	0	0	.60	.01	.01	0	0
703	4	1_c	36	13	5	9	10	0	0	.05	.10	.10	0	0	0	0	0	0	0	0	0
704	4	5_c	36	13	5	18	35	0	0	.70	.55	.55	0	0	0	0	.80	.05	.05	0	0
705	4	5_o	36	13	5	12	19	0	0	.50	.10	.10	0	0	0	0	.60	.01	.01	0	0
706	41/2	1_c	47	15	8	9	10	0	0	.05	.10	.10	0	0	0	0	0	0	0	0	0
707	41/2	5_c	47	15	6	18	35	0	0	.70	.55	.55	0	0	0	0	.80	.05	.05	0	0
708	41/2	5_o	47	15	6	12	19	0	0	.50	.10	.10	0	0	0	0	.60	.01	.01	0	0
709	5	1_c	61	22	8	9	10	0	0	.05	.10	.10	0	0	0	0	0	0	0	0	0
710	5	5_c	61	22	8	18	35	0	0	.70	.55	.55	0	0	0	0	.60	.05	.05	0	0
711	5	5_o	61	22	8	12	19	0	0	.50	.10	.10	0	0	0	0	.60	.01	.01	0	0

*Sea state code value is discussed in Section 4.3.
†The subscript c or o refers to the assumed proficiency of a landing crew. The c represents a Current rating of crews generally inexperienced; o represents a rating for crews who have had the equivalent of wartime Operational experience (see Section 4.3.4).

TABLE C-4
INPUT DATA, DIAGNOSTIC RUNS

Run number	Sea state*	Surf height, ft†	Load time, min			Repair Time, min		Attrition probabilities														Prescribed logistic level, min
								Damaged at beach							Destroyed at beach							
			100 men	1 vehicle	1 lift logistics	minimum	maximum	LVT	DUKW	LCVP	LCM-3	LCM-6	LCM-8	LCU	LVT	DUKW	LCVP	LCM-3	LCM-6	LCM-6	LCU	
800	31/2	1_c	31	12	4	9	9	0	0	.05	.10	.10	0	0	0	0	0	0	0	0	0	none
801	31/2	1_c	31	12	4	9	9	0	0	.05	.10	.10	0	0	0	0	0	0	0	0	0	1200
802	31/2	5_c	31	12	4	35	18	0	0	.70	.55	.55	0	0	0	0	.80	.05	.05	0	0	none
803	31/2	5_c	31	12	4	35	18	0	0	.70	.55	.55	0	0	0	0	.80	.05	.05	0	0	1200
804	5	1_c	61	22	8	10	10	0	0	.05	.10	.10	0	0	0	0	0	0	0	0	0	none
805	5	1_c	61	22	8	10	10	0	0	.05	.10	.10	0	0	0	0	0	0	0	0	0	1200

*Sea state code value is discussed in Section 4.3.

†The subscript c or refers to the assumed proficiency of a landing crew. The c represents a Current rating of crews generally inexperienced; o represents a rating for crews who have had the equivalent of wartime Operational experience (see Section 4.3.4).

competition among serials, and between serials and logistics, for loading facilities at shipside. Since the time to complete the unloading of non-scheduled serials was to be one of the measures reflecting the sensitivity of the ship-to-shore movement, it was considered important to determine the extent to which this time was being affected by the serial and logistic competition. This requirement for a better understanding of what was happening in the runs led to a request for another set, termed by us the "diagnostic" runs, and carried out by NWL.

C.6 Diagnostic Runs

The diagnostic runs (800 through 805) did not play any general unloading, and half of them (800, 802, and 804) did not play any prescribed logistics, in order to simplify the results to assist in analyzing some of the unexpected and puzzling findings of the production runs. In addition, run 702 was repeated as run 702-1, with a change in the random number used in the attrition probabilities.* The inputs used in the 800 series runs are given in Table C-4. The times at which the non-scheduled serials landed in the production and diagnostic runs are given in Table C-5.

Before proceeding to a discussion of the results of both the production and diagnostic runs, it is of utmost importance to present two critical findings which render any interpretation of the results of dubious value at best. An intensive analysis of the diagnostic runs revealed that in no case was the model playing any unloading time for floating dumps or serialized loads of logistics. In addition, a sporadic error within the model was discovered, in which erroneous values for loading and unloading times for craft carrying logistics were occasionally (but unpredictably) being calculated in the process of the runs. The combined effect of the sporadic error and the zero unload times was to prevent the formation of queues both at the beach and at shipside; this unrealistically smooth course of the operation prevented useful study of the effect of environmental changes on these runs. Although NWL made the necessary corrections to the program and offered re-runs, insufficient time and resources remained in the project at that point to permit the complete repetition of our extensive

*As before (Section C.5), the replicated run showed no change in results due to the change in random number used because of the way in which the attrited craft are unloaded and replaced in STS-2 (see discussion at end of C.6). The two serials which were affected in the change from 702 to 702-1 were reflecting the difficulties described in Section C.6, paragraph two.

TABLE C-5
LANDING TIMES (MINUTES) FOR NON-SCHEDULED SERIALS
IN PRODUCTION AND DIAGNOSTIC RUNS

Run no.	Serial number											
	902	814A	814B	732	840	753	363	601	700	1	950	951
700	683	1023	1939	829	1441	890	1780	1166	845	696	1445	2076
701	683	1023	1939	831	1445	894	1784	1972	850	702	1449	1738
702	683	1023	1939	831	1445	894	1784	1172	850	702	1311	1471
702-1	683	1023	1939	831	1445	894	1784	1172	850	702	1449	2078
703	701	1061	2056	851	1509	915	1883	1214	870	712	1460	1726
704	701	1061	2056	851	1509	915	1883	1214	870	712	1550	1865
705	701	1061	2056	851	1509	915	1883	1214	870	712	1460	1726
706	731	1137	2286	893	1637	957	2076	1301	910	734	1608	1657
707	731	1137	2286	893	1637	957	2076	1301	910	734	1608	1657
708	731	1137	2286	893	1637	957	2076	1301	910	734	1608	1657
709	821	1393	3075	1025	2069	1070	2730	1558	1030	760	1995	2340
710-0	821	1393	3075	1025	2069	1070	2730	1558	1030	760	1395	2068
710-1	821	1393	3075	1025	2069	1070	2730	1558	1030	760	1995	2068
710-2	821	1393	3075	1025	2069	1070	2730	1558	1030	760	1995	2068
711	821	1393	3075	1025	2069	1070	2730	1558	1030	760	1995	2068
800	683	1023	1939	831	1445	894	2072	1172	850	702	1311	1471
801	683	1023	1939	831	1445	894	1784	1172	850	702	1449	1471
802	683	1023	1939	831	1445	894	2072	1172	850	702	1311	1471
803	683	1023	1939	831	1445	894	1784	1172	850	702	1449	1471
804	821	1393	3075	1025	2069	1070	3007	1558	1030	760	1727	2044
805	821	1393	3075	1025	2069	1070	2730	1558	1030	760	1727	2044

analysis which would have been required to make effective use of re-runs. Accordingly, and unfortunately, we were forced at that point to discontinue the use of STS-2, and the following discussion treats the results of the production and diagnostic runs as found, including the fallacious results.

Interpretation of the outputs summarized in Table C-5 is facilitated by reference to the inputs of the production runs in Table C-3 and of the diagnostic runs in Table C-4. Recall that our ability to influence the operation geophysically lies in increased off-loading times from ship to craft, reflecting increased sea state, and in increased craft attrition probabilities and repair times at the beach, reflecting increased effective surf heights. We had anticipated being able to examine the independent effects of sea state and surf height, and then the confounding effects to be observed when both elements worsen simultaneously. As indicated above, however, the operation proceeded in an unrealistically smooth fashion, so that the only important impact seen was that of the increased load times, which is a relatively uncomplicated process.

The increase in time for a serial to be landed (shown in Table C-5, as the reader goes from run 700 to run 711) demonstrates the simple additive effect of increasing the input loading time as shown in Table C-3. For example, the input to the simulation specifies that the time to start loading serial 902 is minute number 510. The output shows that for runs numbered 700—702, serial 902 was unloaded at the beach at minute 683, which indicates that the time to load the craft, transit to the beach, and unload required 173 minutes. In runs 709—711 the loading time has not quite doubled (see Table C-3), while the time at which loading started remained the same. The time serial 902 is landed in the 709—711 series is minute 821. This indicates that, in the 709—711 runs, the time to load, transit to the beach, and unload for serial 902 required 311 minutes, an increase of the same factor of slightly less than two by which the loading time was increased.

By comparing times within a constant sea-state subset, it can be seen that the variations of attrition probabilities due to surf at the beach do not affect the time to land the serials. This point can be seen in Table C-5. The runs numbered 706, 707, and 708 are a subset in which the loading times are the same, but the attrition rate varies. Despite the variations of attrition, a specific serial is landed at exactly the same minute in each of the three runs. This same output is evident in runs 709—711, with one exception. Serial 951 is landed 272 minutes later in run 709 than in 710 or 711. This is not an expected consequence, since run 709 represents a more favorable environment than runs 710 and 711. The delay for serial 951 in run 709 is apparently due to competition for shipside loading facilities. The reason all serials have identical unload times even though attrition occurs is that, in the model, attrition affects the craft after unloading; the craft was always unloaded immediately, whether it was attrited or not. The potenially important effect of attrition, as far as the simulation is concerned, is the removal of craft from an availability status. Although this happened to some degree in the particularly adverse surf cases, there were always plenty of additional craft to take up the slack, so that the simulation showed no surf effect.

The following comments on the diagnostic runs relate exclusively to the anomalies which finally led us to identify the trouble spots in the simulation described at the beginning of this section (C.6). The reader can readily see what struck us: when general unloading alone was removed from the runs (runs 801, 803, and 805), the results of the comparable production runs (runs 700, 701, and 709) were essentially duplicated. However, when prescribed logistics play was removed as well (runs 800, 802, and 804), which, if anything, should have speeded up the action, one of the serials (serial number 363) took some five hours longer to land. The process of seeking the cause of this anomaly led us to the discovery of the trouble spots which were described previously.

C.7 Conclusions

If one were to accept the output of the model without question, the conclusion would be that as the sea state grows more adverse the time when the non-scheduled serials arrive at the shore is delayed; increasing surf height merely increases craft attrition statistics with no important effect on the operation. The output would further indicate that the factor that determines the time that a given category of serials arrives at the shore is whether there is competition for the craft-loading facilities at shipside. However, these conclusions, as stated, are not in agreement with observations, as described to us by amphibious personnel listed in Appendix D. The importance of competition for craft loading facilities in a real operation can be minimized by assigning priorities as needs arise. The time a serial arrives at the beach would in reality also be varied by the craft attrition rate, because of delays caused by broaching or repairs. These delays are not reflected in the simulation in the time that the non-scheduled serials are landed on the beach.

In conclusion, it may be said that much was learned in the manipulations of STS-2, but that the model was not suited for environmental study.

APPENDIX D

SEARCH FOR

OPERATIONAL-ENVIRONMENTAL DATA

APPENDIX D. SEARCH FOR OPERATIONAL-ENVIRONMENTAL DATA

D.1 Search for Existing Data

As mentioned in Section 4.3.3, it was found that the recorded data on the quantitative relationship between operational parameters and environmental factors were, almost without exception, applicable only to the so-called "nominal" state, connoting a benign environment. The single exception is discussed later in this appendix.

The search for existing data was extensive; it involved correspondence with, and visits to, many Naval and Marine installations and contractors with experience in the subject of amphibious operations. The following list shows the extent of the search; each organization listed was visited at least once during the period 23 October 1964 to 14 January 1965:

U.S. Naval Weapons Laboratory, Dahlgren, Va.

Office of Naval Research, Code 493, Washington, D. C.

Naval Warfare Research Center (Stanford Research Institute), Menlo Park, Calif.

Southern California Laboratories (Stanford Research Institute), South Pasadena, Calif.

Headquarters, U.S. Marine Corps, Arlington Annex, Va.

U.S. Marine Corps Landing Force Development Center, Quantico, Va.

U.S. Naval Oceanographic Office, Suitland, Md.

Library of Congress, Washington, D. C.

U.S. Naval Amphibious Base, Little Creek, Va., including the staffs of the following units at Little Creek:

- Commander, Amphibious Forces, Atlantic Fleet
- Naval Amphibious School
- Naval Amphibious Training Command
- Naval Amphibious Operational Support Unit
- Naval Amphibious Operations Training Unit
- Marine Corps Landing Force Training Unit
- Naval Amphibious Group 2
- Naval Amphibious Group 4

Naval Beach Group 2

Beachmaster Unit 2

Assault Craft Unit 2

Amphibious Construction Unit 2

Naval Amphibious Squadron 8

Naval Amphibious Squadron 12

Extensive discussion with these staffs provided considerable additional familiarization information with amphibious assault operations and their environment. However, the discussion also confirmed the finding that documented data on landing craft operational characteristics versus environment existed only for the benign or nominal case.

One source, which appeared promising, but which failed to mature, was the Post-exercise reports of previous amphibious exercises, suggested by staff members at the Landing Force Development Center at Quantico. It was hoped that, in cases where the reports showed adverse conditions and consequent difficulty with landing craft, the difficulty would be described quantitatively and would include quantitation of the adverse environment (e.g., surf height). Of some fifty such reports studied, only five made reference to worsening conditions and included some information on their effects (this was not unexpected, since it is not normally included in the objective of such exercises to seek out adverse or worsening environmental conditions). Of the five, only one, a case of severe problems, included quantitation of the worsening surf which caused difficulty, and that changed so rapidly that the specific damage caused could not be related quantitatively to surf height. A subsequent search at Little Creek for surf observations of previous exercises led to the information that the environmental records of these exercises are not normally retained on file, but are primarily for the on-the-spot use of the amphibious commander. This finding thus reinforced the conclusion that the information required would have to be developed from interviews in depth with operating personnel with direct experience in the behavior of the craft involved.

D.2 Sources of Raw Data for Developing Operational-Environmental Dependencies

The principal source of our input data consisted of the interviews to be described later in this section. However, the one documented source mentioned in Section D.2 , which was used in support of our data, will be described first. Through the kindness of one of the staff members of the Naval Amphibious Operations Training Unit, Little Creek, Va., we were made aware of an obsolete Navy training publication (no longer available) from which extracts of pages could be had. The publication was titled Surf Manual, and was of post World War II vintage. The available pages gave graphs presenting the results of observations of a large number of individual LCVP and LCM landings at the Amphibious Training bases at Coronado and Morro Bay, Calif. Because of uncertainties about certain aspects of the data, we could not use it as our exclusive data source for the relation between LCVPs and LCMs and surf height; however, it was used to supplement the new data generated by us. The biggest problem was the lack of specification of the other surf characteristics besides the average height figure quoted, such as the maximum height, type, period, breaker angle, littoral current and wind, which are the inputs from which the Navy now calculates "effective" surf height. Other facts about the data, which must be borne in mind, include first, that the number and causes of the "casualties" (swamping, hanging up on a bar, or broaching) were observed by experienced coxswains (who could distinguish casualties due to poor seamanship from mishaps due to surf) and that all casualties were eliminated which could be ascribed to inexperience, and second, that all information was derived from landings with unloaded craft which spent a very short time on the beach. It was expected that the results would apply to craft carrying troops and staying only a few minutes on the beach, but that casualties would be considerably greater if the craft carried supplies. Finally, the LCM studied was an earlier version than the LCM-6s and LCM-8s now in use. The results are given in Table D-1.

TABLE D-1
LCVP AND LCM CASUALTIES IN SURF

Average breaker height, ft	LCVP casualties, % Beach Slope			LCM casualties, % Beach Slope
	1:10	1:40	1:70	Any less than 1:10
1	0–2	0–2	0–2	0–1
2	0–3	0–3	0–3	0–2
3	0–5	0–4	0–4	0–4
4	2–20	0–5	0–5	0–5
5	20–50	2–7	2–7	0–7
6	> 50	4–12	4–11	2–11
7	N.D.	8–16	7–14	5–14
8	N.D.	13–23	10–20	8–17
9	N.D.	N.D.	14–26	12–21

N.D. = No data.

Finally, our principal data sources were experienced personnel from units presently active in the amphibious forces. The individuals interviewed for detailed estimates of shipside and surf characteristics of craft during the period 30 November 1964 to 18 December 1964 were:

Organization	Position	Rank	Name
Naval Beach Group 2	Operations Officer	LCDR	P. M. Armstrong
Amphibious Group 4	Ship-to-Shore Officer	LCDR	F. C. Caswell, Jr.
Amphibious Group 4	Meteorology & Oceanography	LT	H. H. Henderson
Assault Craft Unit 2	Executive Officer	LT	J. A. DeCarlo
Amphibious Squadron 12	Ship-to-Shore Officer	LTJG	R. W. Morenmon
Beachmaster Unit 2	Operations Officer	LT	W. Gautier
Naval Amphibious School	Boat Instructor	LT	D. M. Studley
Naval Amphibious School	Boat Instructor	LT	R. D. Catoe
Amphibious Opns. Training Unit	Ship-to-Shore Officer	LT	C. Buyers
Amphibious Squadron 8	Ship-to-Shore Officer	LTJG	R. Barnett
Landing Force Training Unit	Embarkation Officer	LT COL, USMC	M. D. Benda
Landing Force Training Unit	Embarkation Officer	CAPT, USMC	H. E. Arney, Jr.
Amphibious Group 2	Ship-to-Shore Officer	LCDR	J. M. Husbands
Beachmaster Unit 2	Executive Officer	LT	P. P. Bascom
Beachmaster Unit 2	Commanding Officer	CDR	F. R. Kaine

The shipside and surf characteristics of craft, as estimated by the experienced officers listed above, and checked where relevant against the data of Table D-1, were treated as described in Section 4.3 of the report and used in our analyses employing the modified STS-2 model as described in Appendix C. It is reiterated that this is a very limited sample used for example purposes, and should not be considered widely applicable.

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13. ABSTRACT Computer simulation is assessed as a means of acquiring quantitative values of the effects that geophysical factors have on Naval and Marine operations. This work is part of a long-range program to develop warfare system concepts that will include, and in part depend on, the effects of changing environmental conditions, to enhance the probability of mission success by improving the prediction, modification, or control of relevant geophysical phenomena. An appropriate military operation and a corresponding computer simulation were sought concurrently: the Naval Weapons Laboratory's STS-2 Simulation Model was tested against the ship-to-shore portion of the amphibious operation (selected from among fifteen military missions previously determined most susceptible to potential geophysical prediction, modification, or control possibilities). This report covers the operation selection study and the detailed analysis of the selected ship-to-shore movement, eliciting the problems of and then quantifying the appropriate geophysical effects, and the results of computer runs of the STS-2 simulation model. It was found that, while the STS-2 and other present models cannot completely reflect this quantification of geophysical impact (primarily because they were not designed with this objective), simulation is still feasible, but will probably require (1) a new, more complex simulation model and (2) a large-scale data compilation and analysis effort. This effort would be justified by the wide ranging applications that such a program might have. Other methods of quantifying the impact of geophysical parameters on complex naval operations should also be sought.

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